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High Place at The Water'S Edge: A Coastal Vulnerability Assessment of the Kiskiak Landscape

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ABSTRACT

Coastal archaeological sites are threatened by a host of environmental change processes, including sea level rise, land subsidence, and shoreline erosion. The rates at which these processes have been occurring are increasing, exacerbated by climate change, and are expected to increase even more rapidly in the future. This will cause further loss of archaeological sites and with them, the loss of our knowledge of how coastal inhabitants lived and interacted with their landscape. My research assesses the vulnerability of prehistoric and Contact period Native American sites situated around Indian Field Creek in Virginia. This area saw multiple prehistoric occupations, culminating in the protohistoric village of Kiskiak, which was part of the Powhatan chiefdom at the time of European contact. Recent archaeological excavations and the careful study of shell middens found in this area have added to our knowledge of how the Kiskiak people dwelled within this landscape and interacted with their environment. However, field observations have revealed that these midden deposits are actively being eroded. My research takes into consideration a variety of environmental and cultural variables to determine which sites in this area are most at risk from the natural environment and which would be the greatest loss to our understanding of the past if they were washed away from the archaeological record. The results of this research presented here provide guidance for environmental and cultural managers to best preserve the archaeological record and our knowledge of the native people of this region.

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I. Introduction

In the following study I consider the impact of sea-level rise on archaeological sites in the Virginia Coastal Plain using analytical techniques drawn from geospatial analysis. While the majority of current sea level rise research centers around existing human infrastructure that will be affected, cultural resource managers have recently started considering sea level rise impacts on coastal archaeological sites (Caffrey and Beavers 2013, Erlandson 2012, Marzeion and Levermann 2014). Previous studies (Boon et al. 2010, Lowery et al. 2012, Reeder-Myers 2015) suggest that the Chesapeake Bay region will be particularly prone to serious and sustained impacts to archaeological resources in coastal and estuarine settings. Just in Virginia alone, Lowery et al. (2012) estimate that with only one foot (0.3 m) of sea level rise, nearly 800 of the 17,000 archaeological sites will be affected. That number increases to nearly 3,000 sites that would be affected with five feet (1.5 m) of sea level rise. My study analyzes a subset of these sites and expands upon previous research in order to identify (a) which sites will be most affected, (b) what sort of coastal change processes will have the greatest effect upon them, and (c) what types of strategies could be implemented to help protect the cultural heritage at these sites.

As an anthropological study, my research centers on the way *social* practices have impacted—and continue to impact—*human* landscapes. My research is theoretically centered in *historical ecology*, which emphasizes a dualistic feedback mechanism of human-environmental interactions: human societies are not only affected by environmental change; they also cause environmental change which will then impact them positively or negatively in the future (Balée 2006). Environmental archaeological research draws on paleoclimatic proxies such as shell and pollen deposits, sediment cores, and tree rings to determine what sort of physical environment past societies lived in (Balée 2006, Dincauze 2000, Riebeek 2005). The archaeological record supplements the paleoclimatic record with evidence of how past societies both modified and adapted to the natural environment (Balée 2006, Erlandson 2012, Erlandson and Rick 2010, Rick and Lockwood 2013, Sandweiss and Kelley 2012). Thus, the archaeological record not only informs us of how people adapted to environmental change in the past, but it can inform current policy for dealing with issues of sea level rise and coastal erosion today. As Erlandson (2012) emphasizes, "Ironically, marine erosion is destroying the very coastal sites that can tell us how past societies adapted to earlier episodes of sea level rise and coastal geographic change that had profound effects on human history."

Previous studies of sea level rise in the Chesapeake region indicate that two particular types of archaeological resources—Native American shell midden sites located along the water's edge and residential settlements located in riverside and estuarine locations—will be hardest hit. Native American shell midden sites are particularly significant sites, and the examples included in this study are no exception to this. These types of deposits accumulate over long periods, which causes them to contain evidence of long-term cultural changes. Equally important, these shell middens also offer evidence of the ways that Native American societies interacted with and transformed an environmental setting over the long term. This makes them crucial long-term archives of both cultural and paleoclimatic data. Since the passage of the National Historic Preservation Act of 1966, Americans have prioritized the identification and protection of archaeological sites as part of the nation's heritage. The potential loss of this knowledge and of the related Native culture history as a result of erosion and inundation would be a tremendous loss of knowledge about past cultural and environmental processes.

Given the importance of Native shell middens as records of human-environmental relations, my study focuses on the impact of climate change and sea level rise within the portion of the Naval Weapons Station Yorktown (NWSY) surrounding Indian Field Creek. The NWSY serves as an ideal location for this study for several reasons. First, the NWSY contains a wealth of archaeological sites, most of which relate to the deep history of Native sites in the region. Secondly, these archaeological deposits maintain a high degree of stratigraphic integrity because the base has avoided the residential development of surrounding areas, and as such most sites remain undisturbed by mechanized plowing or construction. Lastly, as a result of a program of sustained survey and excavation of archaeological sites on NWSY supported by the U.S. Navy, we have detailed knowledge of the archaeological sites on the base. My assessment of archaeological site locations, elevation, and topography on the NWSY points toward the future impacts of climate change on sites located on the base and will enable cultural resource managers to make decisions about how to best preserve these sites before coastal change processes take a further toll upon them.

II. Study Area

In order to understand the role that the landscape of the study area played in the lives of past Native Americans, as well as how that landscape will be affected by coastal change processes, it is necessary to understand the natural features that make up that landscape. My research centers around Indian Field Creek, which branches off of the York River approximately 3 miles west of its mouth, creating a low-energy estuarine setting that is polyhaline, or highly salty, with salinity measures between 18 and 25 ppt (Virginia Institute of Marine Science [VIMS] 2017). The land surrounding Indian Field Creek is made up of riverine terraces, with steep bluffs sloping down to emergent wetland vegetation, which becomes more or less submerged depending on the tide.

Figure II-1. View of Indian Field Creek from the Colonial Parkway (facing southwest).

There is a steep bluff on the northernmost side of the NWSY property facing the river which contains officers' housing known as Mason Row. The bluff is the dividing line between the NWSY property and that which is owned by the National Park Service as part of the Colonial National Historic Park. The Colonial Parkway, owned and managed by the Park Service, runs along the base of the bluff and across the mouth of Indian Field Creek (see Figure II-2 below).

Imagery credit: Virginia Basemapping Program (VBMP) 2011

Figure II-2. Indian Field Creek and the surrounding area.

It is interesting to note that the channel of Indian Field Creek was actually modified in the 1930s when the Parkway was constructed (MacCord and Callahan 2007). Prior to this construction, the base of the bluff was covered in wetlands, which were then filled in and the land was artificially raised in order to accommodate the road being built on top of it (United States Geological Survey [USGS] 1906). This artificially constructed land constitutes some of the lowestlying areas surrounding Indian Field Creek and appears as most of the green and yellow areas on the elevation map shown in Figure II-3.

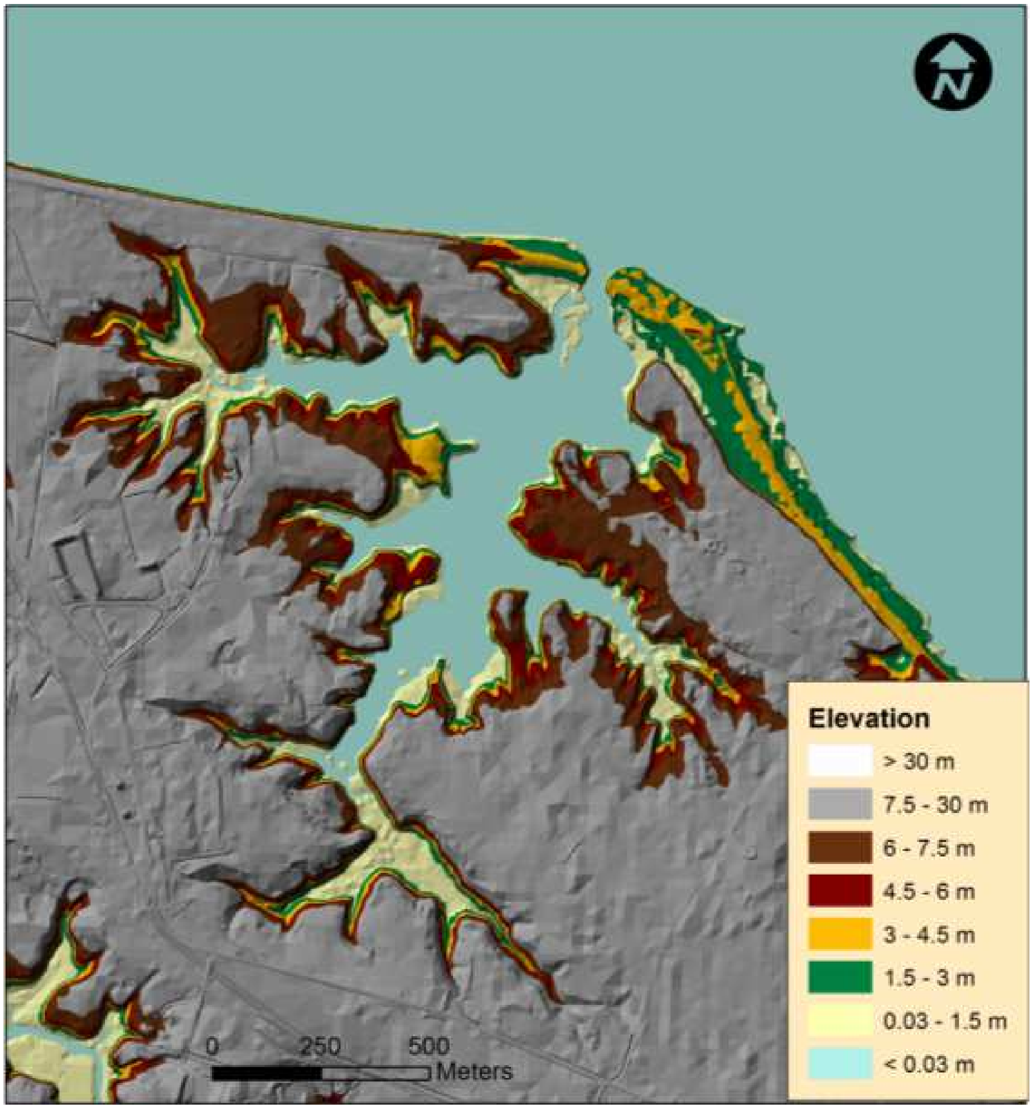

Figure II-3. Elevation of Indian Field Creek and the surrounding area. Based on the 2007 VBMP elevation dataset.

III. Coastal Change Processes

The physical landscape surrounding Indian Field Creek contains a variety of settings in which past societies lived and worked. These settings are threatened by multiple coastal change processes, each of which affects the landscape and the archaeological record in different ways. This section details what these processes are and which will have the greatest impact on archaeological resources.

The three main processes that impact Indian Field Creek and the Chesapeake Bay area as a whole are: sea level rise, land subsidence, and coastal erosion. All of these processes are interconnected and thus magnify the effects of the others. In particular, the amount of land subsidence increases the amount of relative sea level rise, which increases the amount of coastal erosion, and so in turn, they all have an impact on coastal archaeological sites.

A. Sea Level Rise

Researchers conceptualize and measure sea level rise in two ways: absolute sea level rise and relative sea level rise. Absolute, or global, sea level rise is the measure of the increase in volume of water in the world's oceans due to increasing temperature and melting ice caps. The average global sea level rise is currently occurring at 1.8 mm/yr based on calculations presented in the Intergovernmental Panel on Climate Change (IPCC) Report 4. On the other hand, scientists calculate relative sea level rise relative to the land surface at coastal tidal stations.[1] As the land sinks, the difference in vertical elevation between the land surface and water surface will increase. This will indicate a higher rate of relative sea level rise compared to absolute sea level rise because the relative rate of sea level rise also includes the amount of land subsidence (or in rare cases, the amount of land emergence). The fact that the land is sinking in the Tidewater area, in addition to the absolute sea level rising, explains why the rate of relative sea level rise for the Chesapeake Bay equates to nearly twice the global average, at 3.8 mm/yr measured at the Gloucester Point tidal station (Barbosa and Silva 2009, Boon et al. 2010, Fagan 2013, NOAA 2013b).

B. Land Subsidence

Scientists define land subsidence as “downward movement of the earth’s crust relative to the earth’s center.” The main cause for land subsidence along developed coastlines is the pumping of groundwater to provide water supplies for localities. As a result of groundwater removal, the surrounding sediment layers compact, making the ground surface lower than it was before (Barbosa and Silva 2009, Boon et al. 2010). The Hampton Roads Sanitation District is in the process of researching how to pump treated wastewater back into the aquifer to help it recharge, which would help to combat subsidence in addition to providing more water that is available to local communities (Bogues 2016).

[1] At the tidal station at the Yorktown Coast Guard Training Center (which is the nearest tidal station to Indian Field Creek), mean sea level is currently measured at 1.93 meters above the station datum, which is found by taking the average of the high tide level and low tide level over a period of nineteen years (NOAA 2013a).

C. Coastal Erosion

Erosion refers to the wearing down of sanding or rocky shorelines by continual wave action. Erosion is always occurring in coastal areas to some degree, but several factors increase its severity. Increased sea level rise will cause waves to break at a higher elevation along the shoreline, inundating lower elevations more frequently as well as washing sediment away from further up the slope. Hurricanes and other major storm events amplify this process because storm surge affects considerably higher elevations than usual. During Hurricane Isabel, storm surge caused sudden major erosion of a portion of the shoreline along the Colonial Parkway near Indian Field Creek, which required emergency work to stabilize the cliff side and make sure the road was not in danger of collapsing (Hardaway et al. 2006). One of the predicted impacts of future climate change is more frequent and more severe storms (Erlandson 2012), which would cause catastrophic erosion like what happened during Isabel to occur more regularly.

Depending on the geology of a region and the steepness of the slope, the base of a bluff may erode more easily than the material above it. Erosion will continue along the base until there is not enough structural integrity to hold up the material above it. The upper layers will all fall down the slope and fill in, which is a process known as slumping. This occurs frequently in my study area along the York River, where the dominant features are riverine terraces with steep bluffs leading down to the water. In areas where there are prehistoric midden deposits, the Woodland era midden is on top of a fossil layer known as the

Yorktown Formation. As seen at 44YO800 (Figure III-1), an archaeological site on Felgates Creek, just up the river from my study area, the Yorktown Formation layer is eroding, leaving the intact midden precariously jutting out over the beach. When the fossil layer erodes too far, nothing remains to hold up the midden layer and all of it collapses onto the beach (Hardaway et al. 2014). This is far more catastrophic than incremental erosion because all stratigraphic integrity is lost with the collapse of the midden, making it impossible for archaeologists to determine the context of the layers of the midden.

Figure III-1. Visible undercutting of the bank at site 44YO800. Photo courtesy of Bruce Larson, U.S. Navy.

Another common occurrence is tree falls. With the erosion of sandy soil from the bluffs, trees at the top of the bluff become exposed. When they no longer have the root structure to support themselves, they will fall down the bluff with their remaining roots displacing more soil from the bluff along with them, as shown in Figure III-2.

Figure III-2. Tree roots exposed by erosion of the cliff at Cheatham Annex, further up the York River from the study area.

In addition to erosion by undercutting, erosion can occur down slopes, as visible at site 44YO2 in Figure X-1 on page 78. In areas where there is not a lot of plant cover, heavy rain events can cause soil to move down the slope gradient and accumulate at the bottom of the slope. In this case, erosion is occurring at the top of the slope rather than the bottom, but can equally destabilize a cliff side and expose buried archaeological deposits.

D. Impacts on Archaeological Sites

Sea level rise, land subsidence, and coastal erosion all play a role in impacting coastal archaeological sites. Most of the archaeological sites in my study area are situated at the top of steep-sloped riverine terraces that dominate the topography of the region. Because they are located at a higher elevation atop the terraces, *direct* impacts from inundation due to sea level rise and land subsidence are unlikely. However, sea level rise does exacerbate the effects of coastal erosion, which is the primary threat to the archaeological record. In the case study presented in this paper, I examined multiple factors in order to predict the amount and impacts of future erosion on the archaeological sites within the study area.

IV. Heritage Management

When one considers the potential 800 coastal sites in Virginia that could be threatened due to future coastal change processes (Lowery et al. 2012), it becomes readily obvious that not all of them can be saved. Because of the time and monetary investment needed to protect a single site, it then becomes a matter of prioritizing which sites are the most significant and in the greatest danger (Murphy et al. 2009). One major way that archaeological sites are declared as significant is if they qualify for the National Register of Historic Places (NRHP). There are four criteria by which sites can qualify for the National Register: if they are associated with significant historical events (Criterion A), the lives of significant historical people (Criterion B), if they are representative of a certain type, period, or method of construction (Criterion C), or if they have yielded or may yield important information about prehistory or history (Criterion D) (Blanton et al. 2005, King 2003). Based on previous archaeological surveys conducted at the Naval Weapons Station, four archaeological sites surrounding Indian Field Creek are eligible for the National Register under both Criteria A and D (Blanton et al. 2005).

Most of these sites are eligible because of their association with the Protohistoric Kiskiak community, which was one of Powhatan's villages at the time of European Contact (Blanton et al. 2005, Underwood et al. 2003). Contact Period research has often centered on the colonists' experience at Jamestown or may expand to also study Powhatan's main settlement at Werewocomoco, but careful examination of the settlement at Kiskiak broadens the narrative both spatially and temporally (Gallivan 2016). Both Werewocomoco and Kiskiak were persistent places that were inhabited repeatedly over millennia, allowing archaeologists to study the long-term histories of how native people dwelled within the Tidewater landscape and how they both responded to and caused environmental changes. By studying the Indian Field Creek area, we can learn not only the role that Kiskiak played within the Powhatan world but we can also learn about the lifeways of the inhabitants who came before in earlier, less well-documented time periods (Gallivan 2016, King 2003).

Under the National Historic Preservation Act (NHPA), sites are evaluated not only based on their significance, but also based on potential future impacts to the site based on natural or anthropogenic processes. This evaluation also considers how to mitigate adverse effects from future processes, as well as how to best preserve the knowledge contained in the archaeological record at each site. Two common options are: excavation of the site to recover as much data as possible or preservation of the site *in situ* (King 2003). For shoreline sites, *in situ* preservation generally takes the form of attempting to stabilize the shoreline to lessen the rate at which future erosion occurs. In Virginia, the preferred method of shoreline management is the creation of “living shorelines” that are composed primarily of marsh plants planted along the shoreline (Hardaway et al. 2014: 1). These marshes serve to anchor the sediment to prevent erosion, disperse wave action so it does not hit the shore as aggressively, improve the surrounding water quality, and provide habitat for aquatic plants and animals. The marsh edge is often accompanied by stone sills further out into the water that serve as breakwaters and protect the marsh behind them. This approach has proven to be more effective that previous shoreline armoring techniques where stone revetments at the shore were unexpectedly overtopped during storm events, causing erosion of the bank behind them (Hardaway et al. 2010) and was implemented at Werewocomoco in the summer of 2016 (see Figure IV-1). A similar technique involving placing a jute bale filled with straw along the base of the bank in addition to the planting of marsh plants was used at site 44YO800 on Felgates Creek at NWSY, just upstream of Indian Field Creek. This effectively served to protect the shoreline for approximately fifteen years, but now could use replacing as the bank is being undercut once again. The use of living shorelines has proven to be effective in areas that meet certain conditions for wave energy and wind and current directions. The applicability of these methods for the sites near Indian Field Creek is discussed at the end of the case study.

Figure IV-1. Volunteers plant *spartina* marsh grasses along the beach at Werewocomoco, Summer 2016.

Case Study: Indian Field Creek

V. Cultural Context

Indian Field Creek has been the site of multiple occupations dating as far back at the Late Archaic period (Sheehan et al. 1999, Underwood et al. 2003, Gallivan 2016). Data on the Archaic period is limited to a few diagnostic projectile points, though it appears that Archaic period inhabitants preferred locations further away from the York River in higher elevations (Gallivan 2016, Underwood et al. 2003). Late Archaic sites that have been discovered are typically small and ephemeral, with low artifact densities. Blanton et al. hypothesized that these small sites might be staging areas in between larger, more intensively used sites located on lower river terraces, which are now submerged by rising sea levels (Blanton et al. 2005: 251).

Likewise in the Early Woodland period (1000 – 500 BC), sites that have been found are also temporary encampments with small scatters of artifacts (Blanton et al. 2005). More Early Woodland sites have been found to the west of the Chickahominy River than to the east along the James-York Peninsula, which could suggest that the native inhabitants migrated eastward as they shifted their dependence from forest resources in the Early Woodland to estuarine resources in the Middle Woodland period (Blanton et al. 2005, Sheehan et al. 1999). Part of the reason for this shift could be due to the expansion of tidal wetlands and the expansion of more saline water up into the York River, creating the perfect environment for shellfish. This occurred right at the end of the Early Woodland

and the beginning of the Middle Woodland period, based on pollen core evidence gathered from 44YO2 (Blanton et al. 2005).

Going into the Middle Woodland period (500 BC – 900 AD), the number of inhabited sites increased dramatically. In the early Middle Woodland, the Native inhabitants still preferred inland locations where they could hunt deer and squirrel or gather mast and other nuts (Sheehan et al. 1999). However, there began to be a more even mix of inland and coastal settlements that were frequently used as short-term hunting and gathering sites. Throughout the Middle Woodland period, native populations increased, which facilitated a shift from bands to tribes. These population increases also strained the availability of resources, which would explain why we see an expansion into coastal sites and an increasing dependence on estuarine resources (Blanton et al. 2005, Gallivan 2016, Sheehan et al. 1999).

Beginning in the late Middle Woodland period (200 – 900 AD) we see a definite shift towards estuarine resource exploitation. The “hunter-gatherer” people became rather “forager-fishers,” utilizing one or two seasonal rounds in order to take best advantage of both marine and terrestrial resources as they were seasonally available. Encampments would be nearer to the shore to gather clams and oysters in the fall and winter then would move closer to the fish runs in the spring and summer. Estuarine base camps were inhabited repeatedly as part of this seasonal round and for longer lengths of time than early Middle Woodland encampments, as indicated by the higher density of shell and fire-cracked rock found in the archaeological record (Blanton et al. 2005, Dent 1995, Gallivan 2016). It is unlikely that these base camps would be classified as villages at this point, but the people were definitely becoming more sedentary.

In the early Late Woodland period (900 – 1200 AD), we see a reversal of these trends. The amount of oysters being consumed decreased, which put less pressure on oyster populations, allowing them to grow larger, and so we see an increase in the shell size of oysters recovered from this period (Gallivan 2016). It is probable that the population growth of the Middle Woodland period put a strain on marine resources and so the people looked for alternate sources of food. More deer were consumed during the Late Woodland, as their populations likely rebounded during the Middle Woodland while the people were exploiting shellfish (Blanton et al. 2005). Bows and arrows came into use at this time, which made it easier to hunt terrestrial game (Dent 1995). More important, however, was the beginnings of maize horticulture during this period. This transition towards agricultural dependence occurred later in the Coastal Plain region than in other regions, suggesting that the shift was driven by resource depression due to increased population (Blanton et al. 2005, Dent 1995, Gallivan 2016, Sheehan et al. 1999). This also meant that people were living in definite villages for the first time, which were often located in floodplains, while still making use of smaller camps directly on the coasts (Blanton et al. 2005, Dent 1995, Sheehan et al. 1999).

Most of these patterns reach their climax in the late Late Woodland or Protohistoric period (1200 – 1607 AD). Population continued to increase and thus villages became larger, more centralized, and were intended to be more permanent. Typical villages at this time were made up of longhouses and smaller oval-shaped dwellings and were encircled by ditches and/or palisade lines (Dent 1995, Sheehan et al. 1999). Dent (1995) also pointed out that sometimes palisade lines would only encircle part of the village, or would separate the chief's house or sacred spaces from the rest of the village, which could indicate that the palisades served more of a symbolic rather than defensive purpose. Within these villages, people became more sedentary and dependent on agriculture; however, we also see a reversal back to dependence on shellfish and other estuarine resources (Gallivan 2016). Within the archaeological record for the area along the York River, there are a larger number of sites with Late Woodland/Protohistoric components, as well as a higher artifact density at those sites, including large shell middens. A very large number of postholes have also been found, which indicates the creation of more permanent houses (Blanton et al. 2005).

All of these factors contributed to the rise of chiefdoms, specifically the Powhatan chiefdom, which stretched from the Rappahannock River to the James River and west to the fall line (Dent 1995). Powhatan originally inherited leadership over six sub-tribes situated up near Richmond, then moved east, conquering around 25 tribes and adding them to his chieftaincy. While Powhatan was considered the paramount chieftain, he also set up lesser chiefs, or *weroances*, to rule over each individual sub-tribe. Oftentimes when he would conquer a tribe, he'd install one of his relatives as the *weroance* in order to ensure their loyalty (MacCord and Callahan 2007). Kiskiak, located within the study area along Indian Field Creek, was one of these sub-tribes conquered by Powhatan and ruled over by a *weroance*.

Another way that Powhatan maintained power over his sub-tribes was through a tribute system. The *weroances* of each sub-tribe gave tribute to Powhatan as a sign of their subservience and loyalty to him. In return, Powhatan promised protection for the tribes and would also give gifts of prestige goods to the *weroances*. This was a means by which the *weroances* could compete with each other for social and political standing (Mallios 2006). Common prestige goods among the Powhatan were copper ornaments and shell beads, which have been found in Late Woodland/Protohistoric deposits at Kiskiak and other Powhatan sites (Blanton et al. 2005, Dent 1995). Copper was especially important as a symbol of authority among the Powhatan because it could not be found in the Tidewater area and had to be obtained from the Monacan tribes located in the Virginia Piedmont, who were frequent rivals of the Powhatan. This likely explains why the Powhatan were eager to trade with the Europeans for copper, because it reduced their reliance on the Monacan (Hantman 1990).

When the Europeans first arrived, the Powhatan sought to bring them into this exchange and tribute system. Gallivan (2016) argued that the Powhatan divination ceremony that John Smith took part in while being held captive by the Powhatan was actually a means by which he was symbolically brought into the Powhatan world. Later, he returned to Jamestown and Powhatan considered him one of his *weroances* in charge of the James Fort settlers (Gallivan 2016).

However, relations between the Powhatan and the Europeans quickly soured. Mallios made the case that this was because the Europeans were not aware of and thus did not follow Native customs of gift exchanges (Mallios 2006). In spite of this and other reasons for the discord, relations between the Kiskiak and the Europeans were always strained. John Smith commented that when he visited Kiskiak, he “was treated with scorn” by the village’s inhabitants. Later, the Kiskiak were one of the tribes that participated in the uprising of 1622. This led to fierce reprisals by the Europeans, which included burning food supplies and portions of the village in repeated episodes over time. Shortly after this, in 1623, the Kiskiak abandoned the village on the York River and moved northward into Mathews County before merging with the Piankatank tribe (Blanton et al. 2005, Gallivan 2016). This was the end of prehistoric settlement around Indian Field Creek, as the land was quickly divided up amongst prominent European settlers (Blanton et al. 2005).

VI. Selected Sites

A. Site Selection Methodology

Reports from archaeological surveys conducted at Naval Weapons Station Yorktown indicate that most Native American sites from the Woodland Period through the Contact Period[2] are located within 200 meters of a body of water (Sheehan et al. 1999, Underwood et al. 2003). Thus, sites that are located within 200 meters of Indian Field Creek were selected for this study.[3] This was done by generating a 200 meter buffer around the NWSY Streams polygon layer provided by WMCAR. Any sites in the WMCAR Sites polygon layer that intersected the 200 meter buffer were selected for analysis and were saved out to a separate layer. All analysis was based on the locations of the sites in the Sites polygon layer provided by WMCAR. This data is from the early 2000s, so some errors are likely present, though efforts were taken to minimize the amount of error. The sites selected are shown in Figure VI-1. Because of their location within 200 meters of the water's edge, these 27 sites, which are described in more detail in the next section, are particularly vulnerable to erosion and other coastal change processes. My analysis identified which of these 27 sites are the most vulnerable and what would be potential solutions to minimize their vulnerability. Specifics of the analysis conducted are discussed in Section VII.

[2] Many of these sites also contain Historic Period components, however, I limited this study solely to Prehistoric and Contact Period components.

[3] This same methodology can be applied to Felgates Creek and Kings Creek in the future.

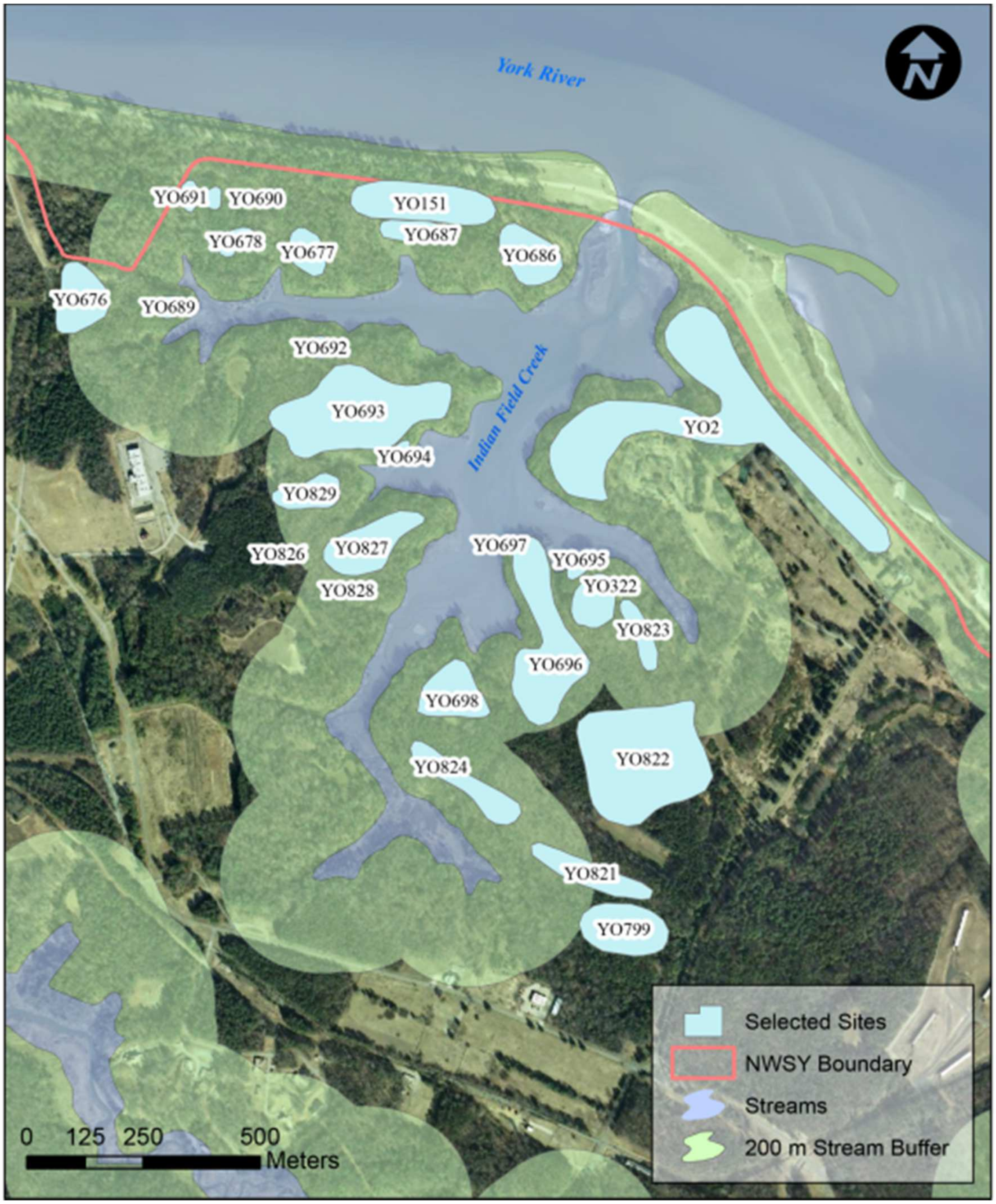

Figure VI-1. Selected archaeological sites which fall within the 200 meter buffer around Indian Field Creek.

B. Summary of Selected Sites

44YO2

44YO2 has been identified as "the Kiskiak Indian site" since 1955 (Green 1983). This was determined in part from John Smith's Map of Virginia and has proved consistent with archaeological excavations conducted there. The site forms a Y-shape, with the top part of the Y made up of ridges surrounding a tributary of Indian Field Creek near its mouth and the lower part of the Y stretching along a bluff overlooking the York River that is currently used as officer's housing along Mason Row. The land at the base of the bluff along Mason Row was originally wetland until it was filled in during the construction of the Colonial Parkway in 1933 (Robinson 1933).

Excavations at 44YO2 have indicated multiple occupations beginning in the Late Archaic Period (2500 - 1200 BC) through the Contact Period (post-1607). Late Archaic quartzite projectile points have been found in addition to a variety of diagnostic ceramics ranging from Middle Woodland Mockley sherds to Late Woodland/Protohistoric Roanoke Simple-Stamped sherds. In the WMCAR survey, the Roanoke Simple-Stamped sherds were recovered from shallower deposits than the other Middle and Late Woodland pottery, leading them to conclude that there were multiple occupations of the site during these time periods (Underwood et al. 2003).

Several shell middens have also excavated, with heavy concentrations of shell located on the ridges overlooking Indian Field Creek. These middens were most likely processing areas for oysters gathered from Indian Field Creek before they were taken into the domestic spaces further along the bluff and consumed there (Gallivan 2016, Underwood et al. 2003). In particular, WMCAR excavated one test unit (Test Unit 4) located on the ridge overlooking the creek that contained a Late Woodland shell midden, but more importantly also contained stratigraphic layers extending from the Protohistoric period all the way back to the Late Archaic, thus providing a complete prehistoric sequence of Native occupations in this area (Blanton et al. 2005). It is of note that field observations in June 2016 clearly indicated erosion of this portion of YO2 immediately adjacent to Indian Field Creek, with shell deposits being exposed and washed down-slope into the creek.

At the other end of YO2, recent excavations along Mason Row suggest that there was a boundary ditch with a palisade line facing the York River, which served as a defensive fortification and a marker of the village boundary during the Protohistoric and Contact period occupation by the Kiskiak tribe under the rule of Powhatan. Similar ditch features and palisade lines were found at the Powhatan capital at Werewocomoco (Gallivan 2016) and at other Native American sites along the Potomac (Blanton et al. 2005), indicating that this was a common practice for the time. The ditch feature was originally discovered during excavation by WMCAR in 2002, with further excavation in 2002 and 2003 to try to determine its extent. At the end of their excavation, they had found 23 meters of the ditch extending along the bluff. Their initial interpretation was that it was a defensive fortification, which is supported by further excavations by Gallivan (Blanton et al. 2005, Gallivan 2016).

Additionally, the WMCAR survey also found deposits from a historic period occupation dating to the 20^{th} century. Most of the artifacts found were historic construction materials, nails, window glass, and various types of bottle glass. These were likely discarded from the nearby troop housing on the NWSY property (Underwood et al. 2003).

44YO151

Little information is available about site 151. It technically lies outside of the boundary of the Weapons Station and is thus on NPS land. It was surveyed by the Park Service, likely back in 1931 when they were beginning construction of the Colonial Parkway. Green reports that all that was found was a sparse scatter of undated artifacts (Green 1983), while the Goodwin survey suggests the existence of a Large Woodland-period village site (Sheehan et al. 1999). Based on the information from the Goodwin survey, this site is likely located to the north of 44YO687, rather than right on top of it, as the WMCAR GIS data indicated (Blanton et al. 2005, Sheehan et al. 1999, Underwood et al. 2003).

44YO322

Very little data is also available for site 322. It is a historic era site that was identified based on historic maps prior to the Goodwin survey. However, this location has never been verified and a more complete survey has not been conducted (Sheehan et al. 1999).

44YO676

44YO676 is located on a riverine terrace overlooking the western end of the northwestern tributary of Indian Field Creek. It is primarily a historic scatter of domestic artifacts, but also contains evidence of prehistoric occupation. The identified prehistoric ceramics were classified as Stony Creek ware, which coupled with the presence of fire-cracked rock, seem to indicate that this was an Early Middle Woodland encampment. It is unclear whether there were multiple prehistoric occupations at this site whose deposits have been conflated together. The historic component of the site contained primarily kitchen, architectural, and personal items, including ceramics, pipe bowls and stems, glass bottle shards, nails, and brick fragments, which indicate that this was a domestic site. This dates back to the mid-18th-century to early-19th-century and may be associated with the Bellfield Plantation site to north beyond the NWSY property (Sheehan et al. 1999).

44YO677

This site is located at the southern end of a north-south facing finger ridge adjacent to the northwestern most tributary of Indian Field Creek. It consisted of a small, very dispersed scatter of prehistoric and historic artifacts. The historic artifacts suggest a small structure or a fenceline. Four of the prehistoric ceramic sherds were Townsend ware, which date the prehistoric occupation to the Late Woodland period. This was likely a small temporary camp. Unfortunately, the site appeared to have been disturbed at some point because both the prehistoric and historic artifacts were found in the same layer (Sheehan et al. 1999).

44YO678

44YO678 is just to the west of YO677 and consisted of historic stoneware, whiteware, and window glass, with an isolated prehistoric flake and fire-cracked rock. The historic artifacts were dated to a 19th- or 20th-century domestic occupation. However, the low artifact density suggested that either this was an impermanent structure or that the site had already eroded considerably (Sheehan et al. 1999).

44YO686

44YO686 is located on a promontory overlooking the main stem of Indian Field Creek and one of its tributaries. It is considered to either be a separate encampment or part of a larger village site (44YO151). It dates to the Middle and Late Woodland periods, evidenced by the presence of Mockley, Townsend, and Roanoke ceramics (Blanton et al. 2005, Sheehan et al. 1999). However, during Phase II survey conducted by WMCAR, all three types of ceramics were found in the same stratographic layers, which indicate questionable stratigraphic integrity for this site (Blanton et al. 2005).

44YO687

44YO687 lies to the west of YO686 and is comprised of two upland terraces connected by a swale that is directly adjacent to the wetlands surrounding Indian Field Creek. Within the swale is an extremely well-preserved shell midden that dates from the Protohistoric period all the way back to the Late Archaic. The uplands, however, only give evidence of a Late Woodland/Protohistoric occupation, which could indicate that the inhabitants moved to higher elevations after 1000 AD, possibly due to sea level rise or an increased amount of horticulture, while the swale remained as a disposal area away from the main living area. This site had one of largest artifact densities of any of the sites in the area, containing a large number of ceramics in addition to faunal remains. Protohistoric Roanoke simple-stamped sherds made up the majority of the ceramics, though sherds dating to the Early and Middle Woodland periods were also found within the midden (Blanton et al. 2005). This site is thought to be either a smaller encampment or possibly related to 44YO151 located to the north of it outside the NWSY boundary (Sheehan et al. 1999).

44YO689 – 44YO691

These three sites all have low artifact densities and limited stratigraphic integrity. Quartz and quartzite flakes were found at all of them, leading archaeologists to believe that YO689 and YO690 were lithic reduction areas. YO691 is thought to have been a small encampment, based on the presence of fire-cracked rock there. Based on the presence of diagnostic ceramics, YO691 is dated to the late Middle Woodland period (200 – 900 AD), YO690 is dated to the Woodland period more generally, and YO689 does not have a determinable date due to the lack of ceramics at that site (Sheehan et al. 1999).

44YO692 – 44YO698

These seven sites are all composed of prehistoric shell middens. Sites 692 through 694 are on the western side of Indian Field Creek, while sites 695 through 698 are on the eastern side. These sites were first identified by the Goodwin drainage survey and were recommended to be more thoroughly surveyed in the future (Sheehan et al. 1999). With the exception of 692 and 697, all of them were resurveyed as part of the WMCAR survey. As part of the resurveying process, no real spatial separation was determined between 693/694 and 695/696, leading to these sites being combined, so that 693 and 694 simply became 693 and 695 and 696 became 696 (Underwood et al. 2003). However, for the purposes of this study, I left them as separate numbered sites, with the understanding that they were separate areas of the same site. This allowed me to determine if one area would be more vulnerable than the other. It is also important to note that the majority of these sites were already eroding along the bluffs of Indian Field Creek at the time of the Goodwin survey (Sheehan et al. 1999).

YO693 contained a prehistoric component dating primarily to the Middle to Late Woodland and Protohistoric periods and a historic component dating to the 18th and 20th centuries. The site contained two loci, with the northern locus only dating through the Middle Woodland period, while the southern locus contained Middle Woodland deposits in addition to more abundant Late Woodland/Protohistoric deposits. This site also contained a rare but quantifiably large Early Woodland component in one test unit (Blanton et al. 2005). There was a separation of ceramics and lithics within the prehistoric component, which suggested that there were separate activity areas for food processing and lithic reduction. This also suggested that the site was used repeatedly as a seasonal base camp with later use as a village site (Underwood et al. 2003).

YO696 contained evidence of multiple prehistoric occupations from the Late Archaic period through the Late Woodland period and two historic occupations dating to the 17th and 19th centuries. The prehistoric component was made up of two concentrations, one in the southwest portion of the site and one on the northern boundary. Lithics were found in both clusters, including a Late Archaic quartzite projectile point in the southwest, while all the ceramics in the southwest cluster were Middle- to Late-Woodland shell-tempered varieties.

YO698 consisted of evidence of a short-term prehistoric occupation from the Middle to Late Woodland periods and historic occupation from the late 18th to early 20th centuries. The prehistoric component was located along the edge of the ridge and contained one diagnostic sand-tempered ceramic sherd, while the historic component suggested two domestic occupations (Underwood et al. 2003).

44YO799

44YO799 is one of the furthest inland sites examined in this study, just barely touching the edge of the 200-meter boundary. It is located off the southeastern-most branch of Indian Field Creek in a relatively flat wooded area. This site is unique in that it is also exclusively a Late Woodland/Protohistoric site. Small Archaic period, Middle Woodland, and Historic components were found, but the artifacts were predominantly Late Woodland/Protohistoric Roanoke ceramics. The fact that no Townsend ceramics were found indicates that this site was a very late occupation and the presence of two Colonial artifacts suggests trade with the European settlers (Blanton et al. 2005, Underwood et al. 2003).

44YO821 and 44YO824

These two sites are located to the west of YO799 on a terrace to the north of a tributary of Indian Field Creek. YO821 contained a small prehistoric component of nondiagnostic artifacts and a historic component dating from the early 18th- to early 19th-centuries consisting of pipe stems, bottle glass, coarse earthenware, creamware, and pearlware, which would suggest a domestic site. YO824 consisted primarily of a Late Woodland occupation on the ridge overlooking Indian Field Creek, but a small historic brick scatter was also found on the periphery of this site (Underwood et al. 2003).

44YO822

44YO822 is a larger inland site made up of a smaller prehistoric component dating from the Middle Woodland to the Protohistoric period and a larger historic component from the 17th- to 20th-centuries. The site is located on a large terrace and a series of ridge points extending towards a tributary of Indian Field Creek to the north. One of these ridges on the north side of the site contained both the prehistoric component, which consisted mostly of shells and a variety of Middle Woodland through Protohistoric ceramic types, and a historic period trash pit, which contained a dense deposit of shell, brick, colonoware, and bottle glass. The rest of the historic deposit indicated a late 18th/early 19th-century domestic occupation, based on pearlware and whiteware found, in addition to coarse earthenware, refined earthware, colonoware, and historic construction materials (Underwood et al. 2003).

44YO823

44YO823 is made up of a historic road grade dating to the late 19th- to early 20th-centuries. The road cut across the base of three finger ridges that stretched north to a tributary on the east side of Indian Field Creek, following higher, more level terrain. It has been associated with the historic Indian Fields Farm, located to the west of the site (Underwood et al. 2003).

44YO826 – 44YO829

These four sites are located on ridge terraces projected over the western shore of Indian Field Creek. All four sites appear to have been used for short-term encampments. Due to the low density of artifacts, 44YO826 and 44YO828 cannot be precisely dated, but YO826 contained both a prehistoric and historic component, while YO828 only contained a prehistoric component. It is likely these two sites were only occupied once or that they were discard sites rather than true occupations (Underwood et al. 2003).

44YO827 and 44YO829 showed evidence of repeated short-term occupations, possibly as a seasonal encampment during the Middle to Late Woodland periods. YO827 contained three loci of artifacts: one made up of a mixture of Middle Woodland and Late Woodland ceramics and fire-cracked rock, one with a Middle Woodland Mockley sherd and a concentration of shell, and the third contained Late Woodland ceramics and lithics. Each locus was thought to be a separate short-term occupation. Diagnostic ceramics from the Middle

Woodland and Late Woodland to Protohistoric periods were found at YO829 at depths that indicated two distinct occupations. This helped to reinforce the idea that this site was reused seasonally throughout the Middle and Late Woodland periods (Underwood et al. 2003).

The majority of these 27 sites bear witness to prehistoric occupations, while half of them were also occupied during the historic era. They are distributed around the eastern and western sides of Indian Field Creek, though there are none along the southwestern corner of the drainage. They span a broader temporal range from the Late Archaic through the Contact period, with some sites such as YO2 being repeatedly occupied during that entire span of time. Figure VI-2 shows which sites have prehistoric and/or historic occupations, while Figure VI-3 shows the range of prehistoric time periods for each selected site.

Figure VI-2. Selected sites based on prehistoric and historic occupations. Imagery from VBMP 2011, site polygon data from WMCAR.

Figure VI-3. Selected sites symbolized based on prehistoric era occupations. Multiple colors per polygon indicate multiple time periods. Imagery from VBMP 2011, site polygons from WMCAR.

VII. Methodology

To determine the vulnerability of the selected sites, I chose to construct a Coastal Vulnerability Index, or CVI. This is a tool frequently used by coastal managers that takes into account multiple variables - such as elevation, historic rates of erosion, and sea level rise and land subsidence rates - and assigns them a numerical ranking between 1 (least vulnerable) and 5 (most vulnerable) so they can be compared with each other to produce a total ranking of vulnerability. This approach allows for comparing both quantitative and qualitative variables and can be used to make management decisions over large areas, such as entire coastlines, or with a large number of archaeological sites being analyzed (McLaughlin and Cooper 2010, Reeder et al. 2010, Thieler and Hammar-Klose 2000). In contrast, when looking at smaller study areas, such as Indian Field Creek, it is common to simply calculate rates of erosion on a site-by-site basis and use regression analysis to predict future erosion (Maio et al. 2012, Reeder et al. 2010). However, I chose to construct a CVI because it allowed me to consider more variables besides just erosion to determine the vulnerability of the physical environment. This approach also allowed me to take into consideration cultural variables in addition to the environmental variables, so that I could factor in each site's significance to the archaeological record as well as its vulnerability to the physical environment. Many studies only take the environmental factors into consideration, but also examining the cultural factors is important for heritage management planning purposes.

A. Selection of Environmental Variables

In Thieler and Hammar-Klose’s study, they looked at six different variables: geomorphology, historic rate of shoreline erosion, coastal slope, relative sea level rise (which includes land subsidence), wave height, and tidal range (Thieler and Hammar-Klose 1999, 2000). In later studies by Reeder-Myers et al. (2010, 2015), the same variables were considered, although a few were excluded because they were constant across the study area. She also added the distance from the site to the shoreline and the elevation and land use of each site. I followed this approach by taking into account the historic rate of shoreline erosion, coastal slope, distance to the nearest drainage (shoreline or wetland), and the minimum elevation of each site as my environmental variables.

Firstly, the historic rate of erosion for a site can be used to predict the future rate of erosion at that site. If the site has been eroding at a certain rate, without human intervention it is safe to assume that it will continue eroding either at that rate or at a higher rate. Coastal slope can be used as both a measure of the future erosion rate and the inundation potential of a site. A shallower slope of the land adjacent to the shoreline will be more vulnerable to inundation during extreme weather events, but additionally will be subject to a faster rate of shoreline retreat than an area with a steeper slope (Thieler and Hammar-Klose 1999). However, if a slope is too steep, it is in danger of being undercut by wave action, which will erode the base of the slope, causing the top of the slope to slump, which would destroy the stratigraphy of the shoreline.

Looking at the variables that Reeder et al. (2010) added to Thieler and Hammar-Klose's analysis, Reeder et al. emphasize the importance of the distance to the shoreline, given that sites closer to the shore will be more at risk than those further away, regardless of elevation. However, the shoreline data that I received did not include the smaller drainages of Indian Field Creek and the wetland areas around the shoreline, so I found that the distance to the nearest wetland area was a more accurate measure of shoreline encroachment on archaeological sites. In the areas where there are not wetlands immediately adjacent to the shore, I used the distance from the site to the shoreline. In terms of elevation, I specifically used the minimum elevation of each site, rather than a mean elevation, because the area with the lowest elevation would be most at risk.

However, I was limited in my evaluation by the small size of my study area. The only source of data for wave height and tidal range would have come from a NOAA tidal station located at the Yorktown Coast Guard base, in which case the values would be the same for the entire area of Indian Field Creek and thus would not affect the results in any way. Likewise, the approximate rate of relative sea level rise is 3.8 mm/yr based on the NOAA tide gauge at Gloucester Point (NOAA 2013), so the only variation that would be present in that value across the study area would come from land subsidence. In Boon et al.'s (2010) study of ten different tidal gauges across the Chesapeake Bay, land subsidence made up 50-60% of the amount of relative sea level rise, so the fact that the land is sinking is the main reason why the rate of sea level rise for the Chesapeake Bay is twice the global average (Barbosa and Silva 2009, Boon et al. 2010). I attempted to calculate the amount of land subsidence across the study area by comparing two digital elevation models (DEMs) from 1963 and 2013 in order to see how much the elevation of the study area changed over that fifty year time period. However, due to the lower resolution of the 1963 DEM (10-meter resolution as opposed to the 1-meter resolution of the 2013 LiDAR), I was unable to gather accurate results, so I was unable to consider land subsidence as a variable for my CVI.

I also attempted unsuccessfully to analyze geomorphology and land use for the study area. Geomorphology can be used as a measure of the erodibility of a shoreline based on what sort of natural features each site is located on, as a sandy beach will be much more prone to erosion than a rocky one. However, my entire area is in the coastal plain, it is all part of the Shirley Formation geologically (Schweitzer 2013), and it would all classify as an estuarine setting following the USGS criteria for geomorphology in Thieler and Hammar-Klose (1999, 2000) so the value for geomorphology would be constant across the site. I then tried to use a broader variable of land cover, given that wetlands would be more vulnerable than uplands and that upland areas of residential or commercial use would be more vulnerable than forested uplands. Reeder-Myers et al. (2010, 2015) also included land use as a way to determine the modern-day human impact on each site. However, the vast majority of the sites examined would be classified as forested uplands, so there was not enough variability to consider this as a separate variable.

B. Selection of Cultural Variables

For my analysis, I focused on two cultural variables: eligibility for the National Register of Historic Places (NRHP) and the area of each site. I used NRHP eligibility as a proxy for the significance of each site, assuming that the sites with the richest cultural deposits would be more likely to be eligible for the NRHP. Additionally, I took into account the size of each site on the basis that a large village site with broad temporal depth would be a greater cultural resource than a small dispersed scatter of artifacts.

C. Calculation of CVI

In Thieler and Hammar-Klose's study, they simply took a geometric mean of all the variables (Thieler and Hammar-Klose 1999, 2000). Reeder et al. (2010) argue that this does not account for the fact that some variables will have a greater impact than others and so they propose several equations using weighted means instead. However, there is a broad range of variability as to which variables are weighted more heavily than others; this is entirely subjective based on the relative importance the researcher places on each variable (McLaughlin and Cooper 2010). Because of this, I decided to take unweighted averages of all the variables. This also allowed me to weigh the cultural variables evenly with the environmental variables.

The equation to calculate the Coastal Vulnerability Index is as follows: $CVI = \frac{D+E+cs+er+NRHP+ar}{6}$, where D = distance to shoreline, E = minimum elevation, cs = coastal slope, er = historic rate of erosion, NRHP = NRHP eligibility, and ar = area of the site. More detail on how each of these variables was calculated will be presented in the next section.

VIII. Analysis and Results of Environmental Variables

A. Historic Rate of Erosion

The Shoreline Studies Program at the Virginia Institute of Marine Science (VIMS) has already analyzed rates of shoreline erosion and accretion for the York River by comparing the shorelines on aerial imagery from 1937 and 2009. However, they did not include Indian Field Creek in their analysis (see Figure VIII-1) because the width of the creek was smaller than their unit of analysis (Milligan et al. 2010). Therefore, I sought to replicate their analysis of historic erosion for the shorelines around Indian Field Creek.

Figure VIII-1. Web map viewer showing the previous VIMS analysis of shoreline erosion rates for the York River.

I obtained shapefiles of the1937 and 2009 shorelines that were digitized to mean low water from the VIMS Shoreline Studies program. The first step in quantifying the amount of distance between the two shorelines was to construct transects that intersected both shorelines using the Digital Shoreline Analysis

System, or DSAS, an ArcGIS extension developed by USGS (Thieler et al. 2008). The transects were constructed to be 100 meters long and spaced 50 meters apart. After this, I visually reviewed the individual transects and edited them so they were not overlapping each other or the shoreline multiple times. This process is shown in Figure VIII-2. The final transects along with the 1937 and 2009 shoreline boundaries are shown in Figure VIII-3.

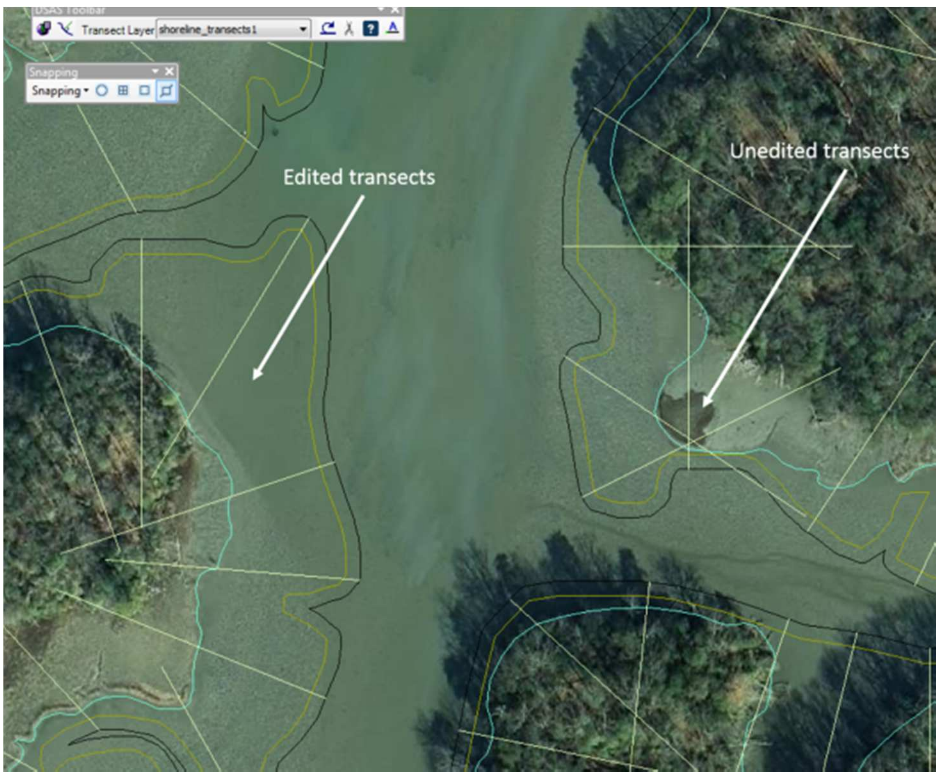

Figure VIII-2. Transects were auto-generated by DSAS and then edited to remove overlap.

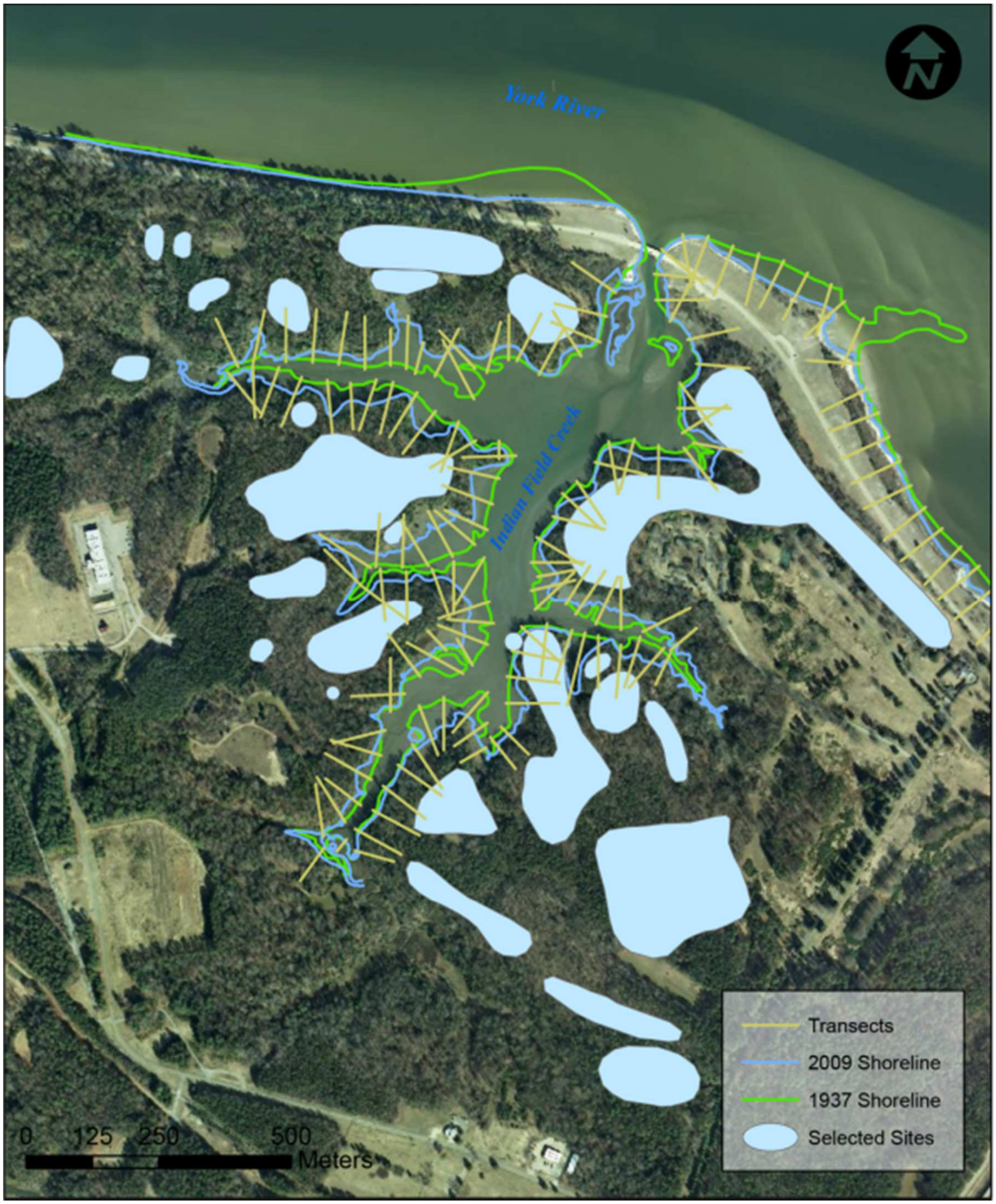

Figure VIII-3. Indian Field Creek showing the 1937 and 2009 shoreline boundaries and the generated transects that intersect them.

After the transects were cleaned up, I used DSAS to calculate the amount of shoreline change at each transect location. This is measured by two statistics:

the net shoreline movement (NSM) and end point rate (EPR). The NSM is simply the amount of distance between the two shorelines at each transect location. The EPR takes the NSM and divides it by 72, which is the number of years between the two shoreline measurements. This provides a measure of the amount of shoreline change per year. If these values are positive, that means shoreline accretion is occurring; however, if they are negative, as they all were in this case, that means shoreline erosion is occurring.

I then took the EPR and NSM rates from each transect point and interpolated the rates of shoreline change for the entire distance around Indian Field Creek. I did this by first constructing a polygon of the distance between the 1937 and 2009 shorelines, which I then split into smaller segments at each transect. Each of these smaller polygons was assigned EPR and NSM values that were the average of the transects on either side of the segment. These values were classified into five categories and symbolized accordingly, as shown in Figures Figure VIII-4 and Figure VIII-5.

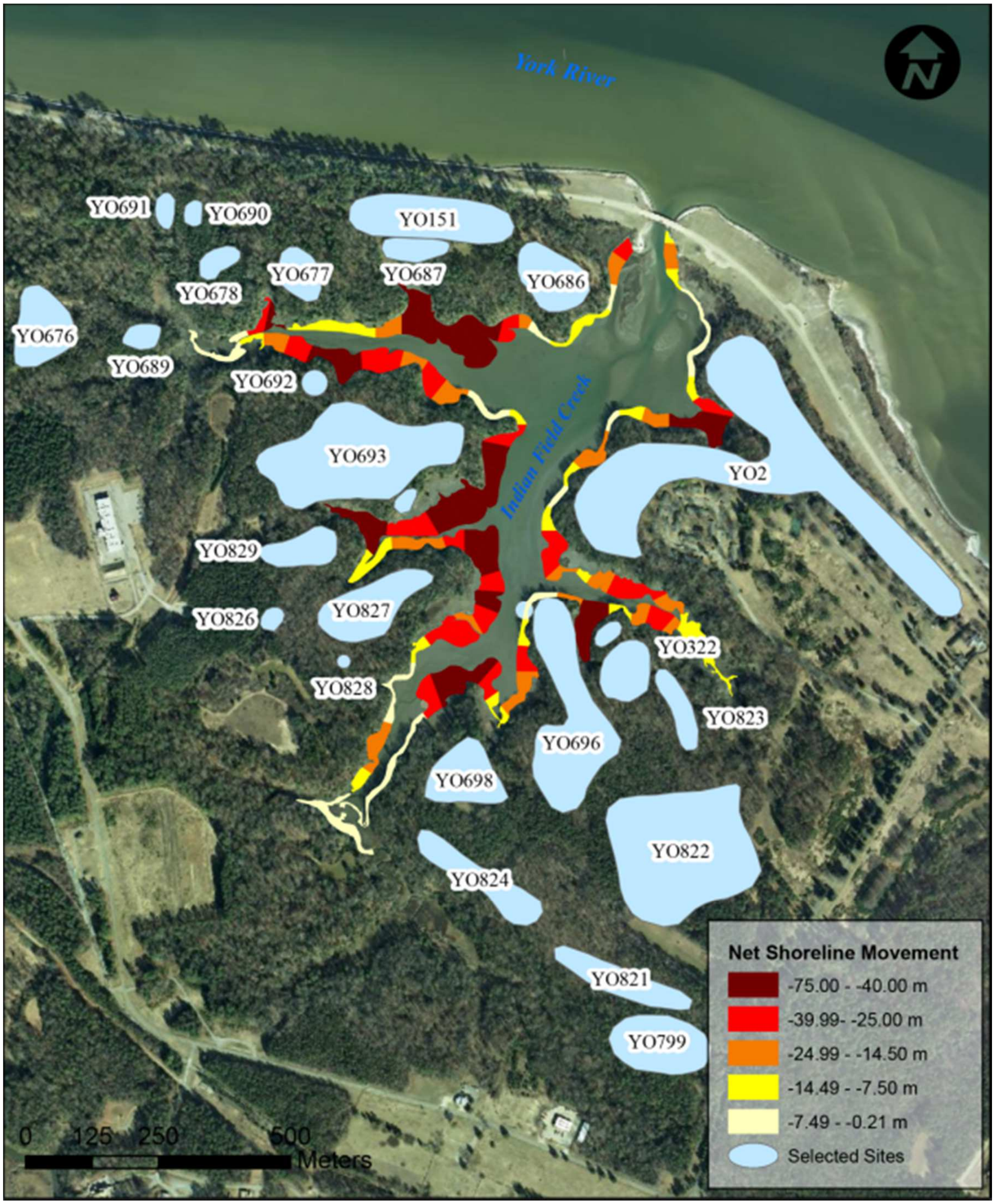

Figure VIII-4. Net Shoreline Movement (NSM) for Indian Field Creek. This reflects the total amount of erosion that occurred between 1937 and 2009.

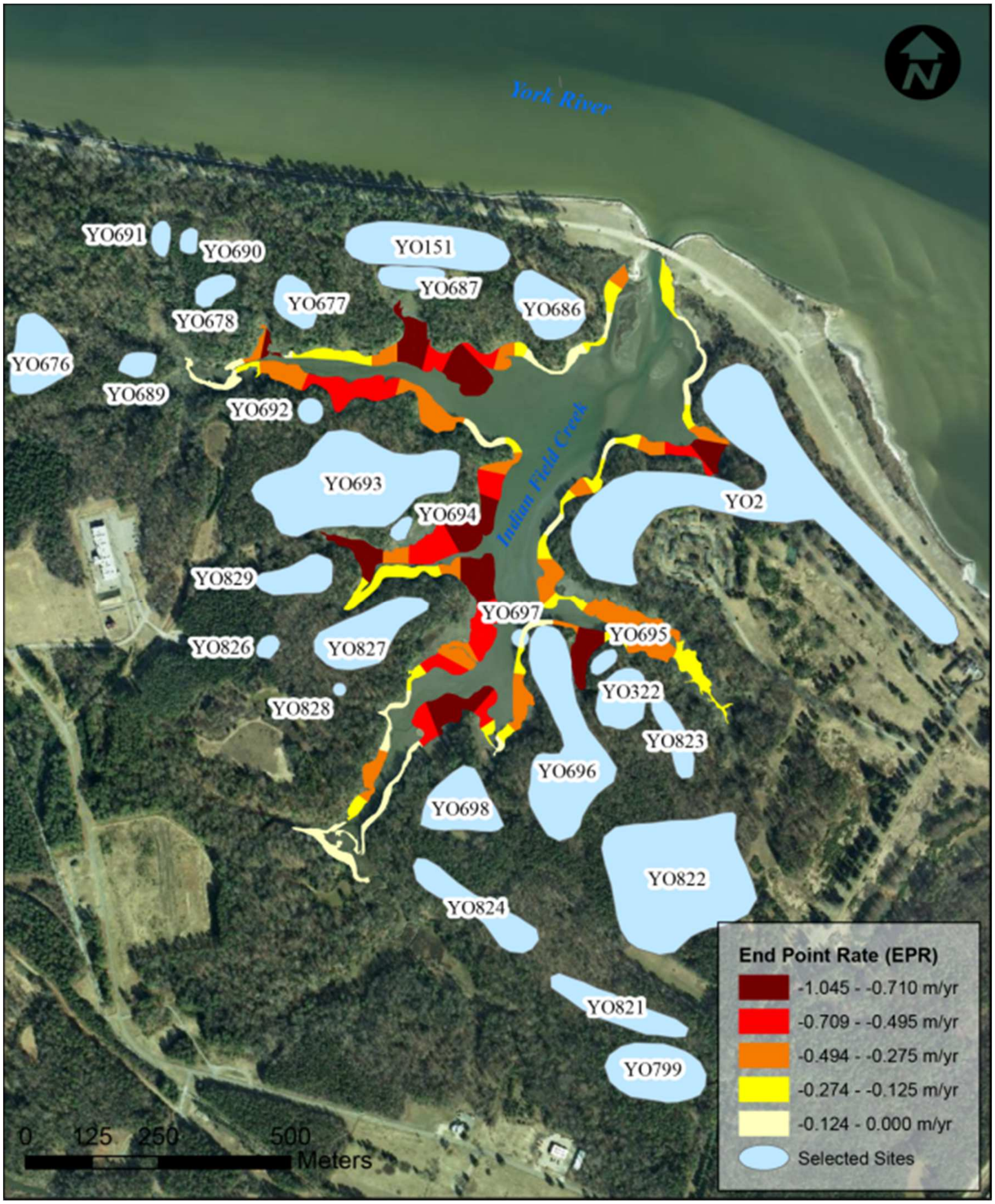

Figure VIII-5. The End Point Rate (EPR) for Indian Field Creek. This is the total amount of shoreline erosion divided by the amount of time (72 years) to give a rate of erosion per year.

The problem now was how to associate the rate of erosion occurring along the shorelines nearest to each archaeological site with the sites themselves. Some of the larger sites in particular encompass long stretches of shoreline with varying rates of erosion and so I thought it was important to take that into consideration in the analysis. To that end, I defined a shoreline reach polygon for each archaeological site, which I defined as the shoreline or shorelines nearest each archaeological site, which would have the most impact on that site. Some sites were given multiple shoreline reach polygons in order to better represent different shoreline conditions. The shoreline reach polygons are displayed in Figure VIII-6.

In order to calculate the average amount of historic erosion, the average NSM and EPR values were calculated for each transect that fell within each shoreline reach. The NSM (total erosion) values ranged from 3.3 meters of erosion to 54 meters of erosion and the EPR values ranged from 0.05 meters of erosion per year to 0.75 meters of erosion per year. The EPR values were divided into five classes and symbolized accordingly, as shown in Figure VIII-7. The values with the highest rates of erosion were assigned as vulnerability ranking of 5, with the lowest values being assigned a 1. The NSM and EPR values along with the ranking for each site and shoreline reach are shown in Table 1.

Figure VIII-6. The shoreline reach polygons generated for each archaeological site. Some sites have multiple shoreline reaches (such as YO2 and YO696), while some shoreline reaches overlap for multiple sites (such as YO687 and YO151).

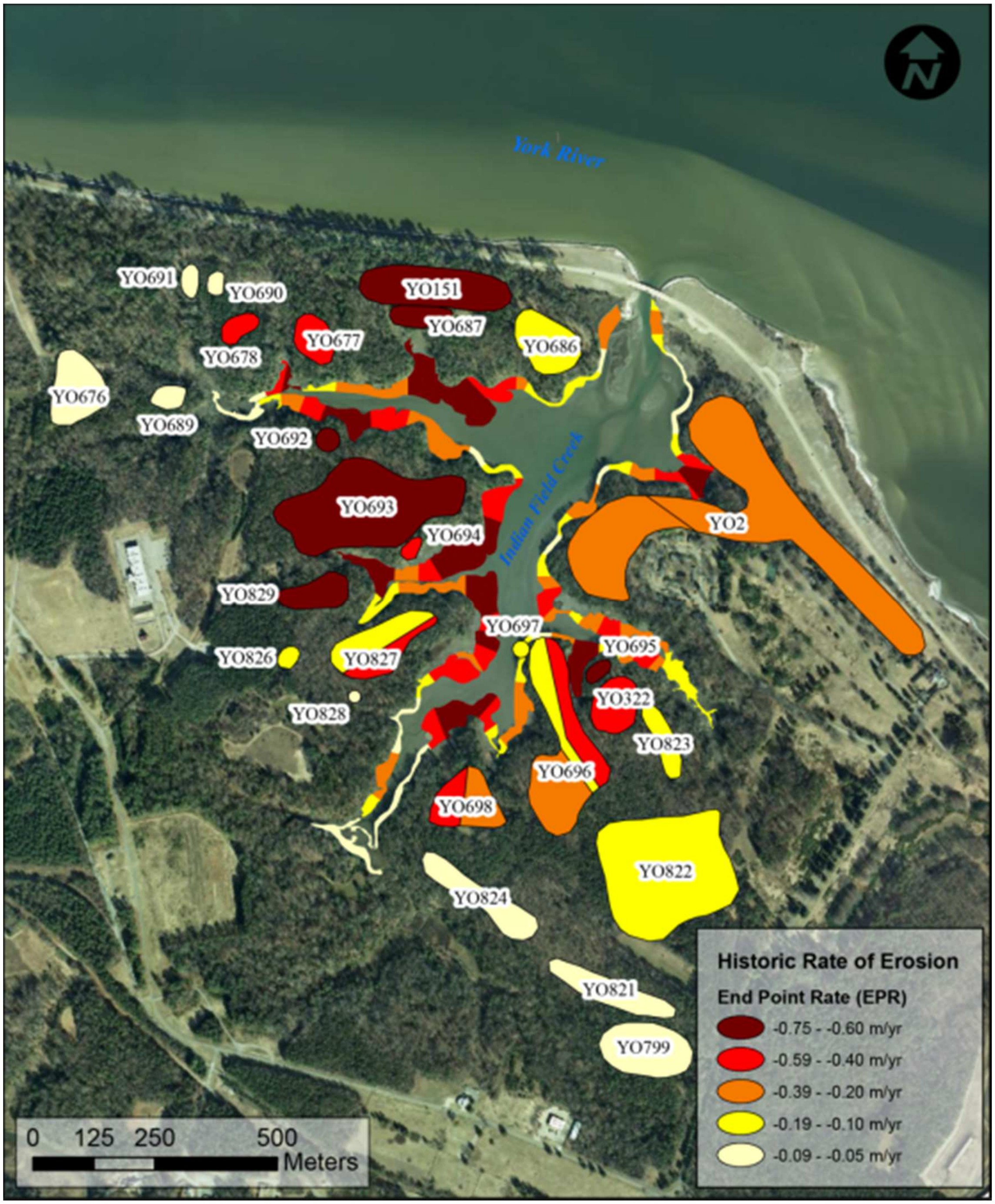

Figure VIII-7. Historic rates of shoreline erosion (shown as rate of erosion per year) for each site based on shoreline reach.

Site Number	Shoreline Reach	EPR (m/yr)	NSM (m)	Rank
YO2		-0.27	-19.72	3
	YO2 Reach 1	-0.31	-22.49	3
	YO2 Reach 2	-0.23	-16.96	3
YO151		-0.66	-47.51	5
YO322		-0.56	-40.61	4
YO676		-0.05	-3.31	1
YO677		-0.44	-31.06	4
YO678		-0.41	-29.49	4
YO686		-0.15	-10.64	2
YO687		-0.66	-47.51	5
YO689		-0.05	-3.31	1
YO690		-0.05	-3.31	1
YO691		-0.05	-3.31	1
YO692		-0.64	-45.89	5
YO693		-0.75	-54.12	5
YO694		-0.55	-39.20	4
YO695		-0.61	-44.09	5
YO696		-0.29	-20.63	3
	YO696 Reach 1	-0.44	-31.22	4
	YO696 Reach 2	-0.19	-13.69	2
	YO696 Reach 3	-0.24	-16.98	3
YO697		-0.11	-7.27	2
YO698		-0.38	-27.40	3.5
	YO698 Reach 1	-0.36	-25.68	3
	YO698 Reach 2	-0.40	-29.11	4
YO799		-0.06	-4.55	1
YO821		-0.06	-4.55	1
YO822		-0.15	-10.55	2
YO823		-0.14	-9.95	2
YO824		-0.06	-4.55	1
YO826		-0.15	-10.72	2
YO827		-0.31	-22.61	3
	YO827 Reach 1	-0.43	-30.93	4
	YO827 Reach 2	-0.20	-14.29	2
YO828		-0.06	-4.05	1
YO829		-0.75	-53.91	5

Table 1. The EPR and NSM statistics for each archaeological site, along with their vulnerability ranking. The sites with multiple shoreline reaches are broken down by reach, as well as giving an average value for the entire site.

Looking at the maps, it is clear that more erosion is occurring on the western shore of Indian Field Creek than the eastern shore. This could be a result of the prevailing wind direction causing more waves to break on the western shore as opposed to the eastern shore. This greater amount of wave action would cause the western shore to erode at a faster rate.

Also visible are some areas where new tributaries and drainages are forming along the sides of the creek. Because these drainages did not exist in 1937, they appear as areas of massive erosion. If these drainages continue to form and erode at the same rate as they did between 1937 and 2009, they will threaten the nearby archaeological sites. This explains the high vulnerability scores for sites such as YO687, YO692, YO695, and YO829. By analyzing the historic rate of erosion that has occurred over the past 70 years, it is easier to identify which areas of Indian Field Creek are eroding faster than others and thus which archaeological sites (or parts of sites) are most threatened if the erosion rates remain constant.

B. Coastal Slope

As discussed at the beginning of this paper, coastlines with slopes at either extreme will be highly vulnerable. If the slope of the shoreline is really shallow, it can easily be inundated. Because of this, Thieler and Hammar-Klose (2000) gave sites with shallow slopes a higher vulnerability ranking than those with steeper slopes. However, very steep slopes are also in danger of being undercut by wave action, which will erode the base of the bluff until it loses structural integrity and slumps downward. This scenario is considerably more common in and around my study area, so I identified steeper slopes as more vulnerable than shallower slopes.

Using the Slope function found in the Spatial Analyst tools in ArcMap yielded a raster that gave a slope value between every pixel in the Digital Elevation Model (DEM) for the study area. While this gave an indication of where the steepest parts of the bluff were all the way around Indian Field Creek, it did not allow for quantitative comparison between sites. In order to better quantify the slope of the bluff adjacent to my selected sites, I constructed another set of transects. (The transects constructed for the shoreline change analysis could not be reused here because they were out in the water and not extending up the bluff in most instances.) I set the length of each transect to be 50 meters which captured just the main slope of the bluff and not the flat terrace at the top of the bluff and allowed the transects to be compared directly. As you can see in the slope profile in Figure VIII-8, there are steeper and less steep segments along the transect, for which the slope was calculated for each segment. ArcMap stores that information internally and then returns the minimum, maximum, and average slope along the line. Originally, I used the average slope to determine vulnerability. However, some transects had a high amount of variability which was masked by using the average. In the end, I used the maximum slope to determine vulnerability because it would be the area with the sharpest amount of change.

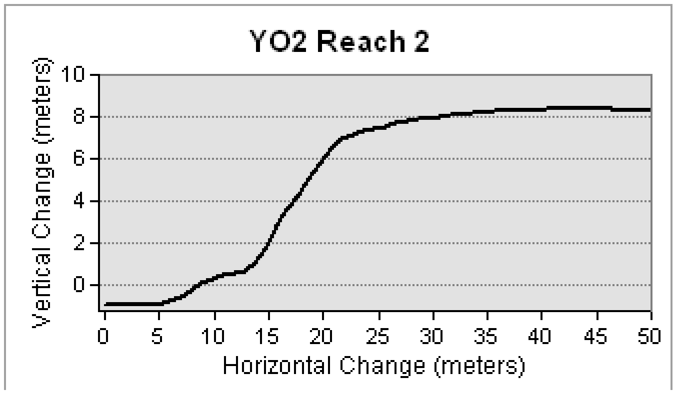

Figure VIII-8. Slope profile graph for one of the transects in Reach 2 for 44YO2. The slope abruptly increases between 15 and 20 meters in from the shoreline.

After these statistics had been calculated for each individual transect, I analyzed the transects in terms of shoreline reaches again. I used the same shoreline reach polygons used in the historic erosion rate analysis and then calculated the maximum, minimum, and average slope values for all the transects that fell within each polygon. These values are shown in Table 2. From there, I took the maximum slope value for each shoreline reach and assigned it a vulnerability ranking between 1 and 5. The vulnerability rankings for each site, along with the individual slope transects, are shown in Figure VIII-9. The results of the ArcMap slope function identifying the steepest parts of the bluffs around the entire creek are shown along with the vulnerability rankings in Figure VIII-10.

Site Number	Shoreline Reach	Minimum Slope	Maximum Slope	Average Slope	Slope Rank
YO151		0.04	105.66	15.79	4
YO2		0.00	136.79	17.92	4.5
	YO2 Reach 1	0.00	121.84	20.85	4
	YO2 Reach 2	0.13	136.79	14.98	5
YO322		0.07	133.89	15.83	5
YO676		0.67	31.17	12.48	1
YO677		0.15	90.06	13.17	3
YO678		0.07	86.49	13.89	3
YO686		0.53	55.50	15.52	2
YO687		0.04	105.66	15.79	4
YO689		0.16	82.12	18.19	3
YO690		0.71	30.25	13.37	1
YO691		0.45	54.48	14.42	2
YO692		0.01	105.26	15.05	4
YO693		0.04	78.53	15.03	3
YO694		1.54	78.53	18.96	3
YO695		0.07	70.81	17.99	2
YO696		0.03	144.26	14.88	3
	YO696 Reach 1	0.03	144.26	16.01	5
	YO696 Reach 2	0.07	92.07	14.68	3
	YO696 Reach 3	0.10	42.26	13.95	1
YO697		0.62	59.32	17.56	2
YO698		0.07	62.09	15.37	2
	YO698 Reach 1	0.07	62.09	15.37	2
	YO698 Reach 2	0.07	62.09	15.37	2
YO799		0.09	36.09	15.80	1
YO821		0.02	62.71	21.24	2
YO822		0.13	60.15	12.26	2
YO823		0.16	98.71	14.33	3
YO824		0.11	54.85	22.96	2
YO826		0.94	61.36	15.57	2
YO827		0.00	86.07	14.43	3
	YO827 Reach 1	0.01	86.07	13.26	3
	YO827 Reach 2	0.00	80.91	15.60	3
YO828		0.01	85.05	14.29	3
YO829		0.08	79.54	15.38	3

Table 2. Minimum, maximum, and average slope values for selected sites. For sites with multiple shoreline reaches, the minimum, maximum, and average of all the reaches was taken to give one value for the entire site.

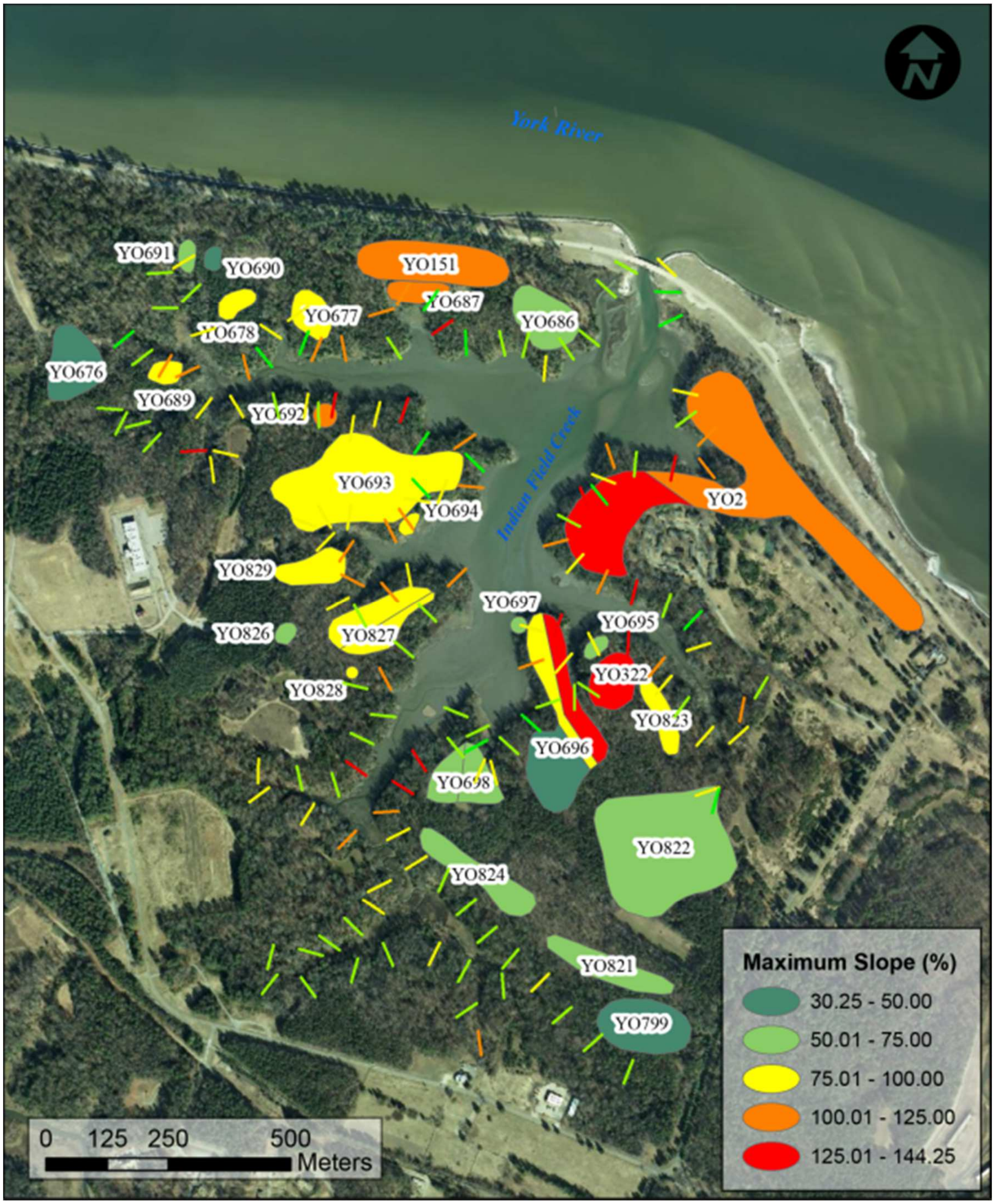

Figure VIII-9. The slope transects and slope vulnerability rankings for each site.

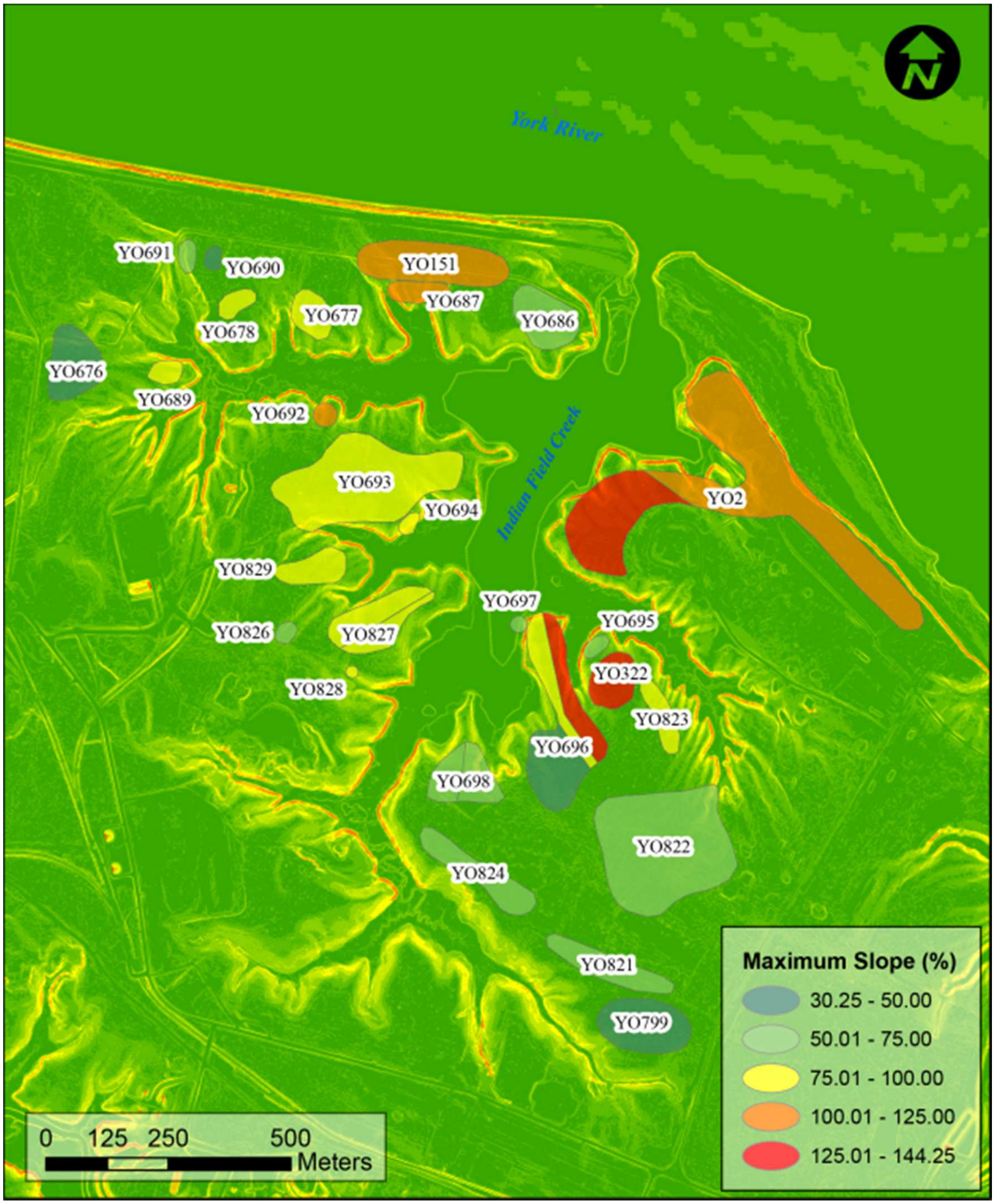

Figure VIII-10. The background layer shows the difference in slope between each pixel. The red areas are steeper slopes (greater amount of change), while the green areas are flatter (less amount of change). This identified the steepest parts of each site.

C. Elevation

I wanted to identify the minimum elevation for each selected site. Knowing where the ground was the lowest helps to identify where the site is most at risk of inundation. I used the zonal statistics tool in ArcMap to calculate the lowest value from the digital elevation model (DEM) for each site polygon. Then I used the raster calculator to determine exactly which cell in the DEM contained the minimum value for each site and then exported that to a point feature class. I was then able to associate the points back with the selected sites which allowed me to add the elevation attributes to the site polygons. The sites were then classified based on their minimum elevation, with the lowest elevations being given the highest vulnerability ranking and the highest elevations being given the lowest vulnerability ranking. Figure VIII-11 shows the selected sites classified by vulnerability ranking as well as the lowest points for each site. Table 3 shows the minimum elevation at each site.

As one might expect, the archaeological sites that are further inland along tributaries of Indian Field Creek have a higher elevation than those along the main stem of the creek. The average minimum elevation of all the sites is 3.9 meters and seven of the 27 sites have minimum elevations that are less than 1 meter; this is generally where the site polygon extends all the way down to the shoreline, such as at YO2, YO687, and YO697.

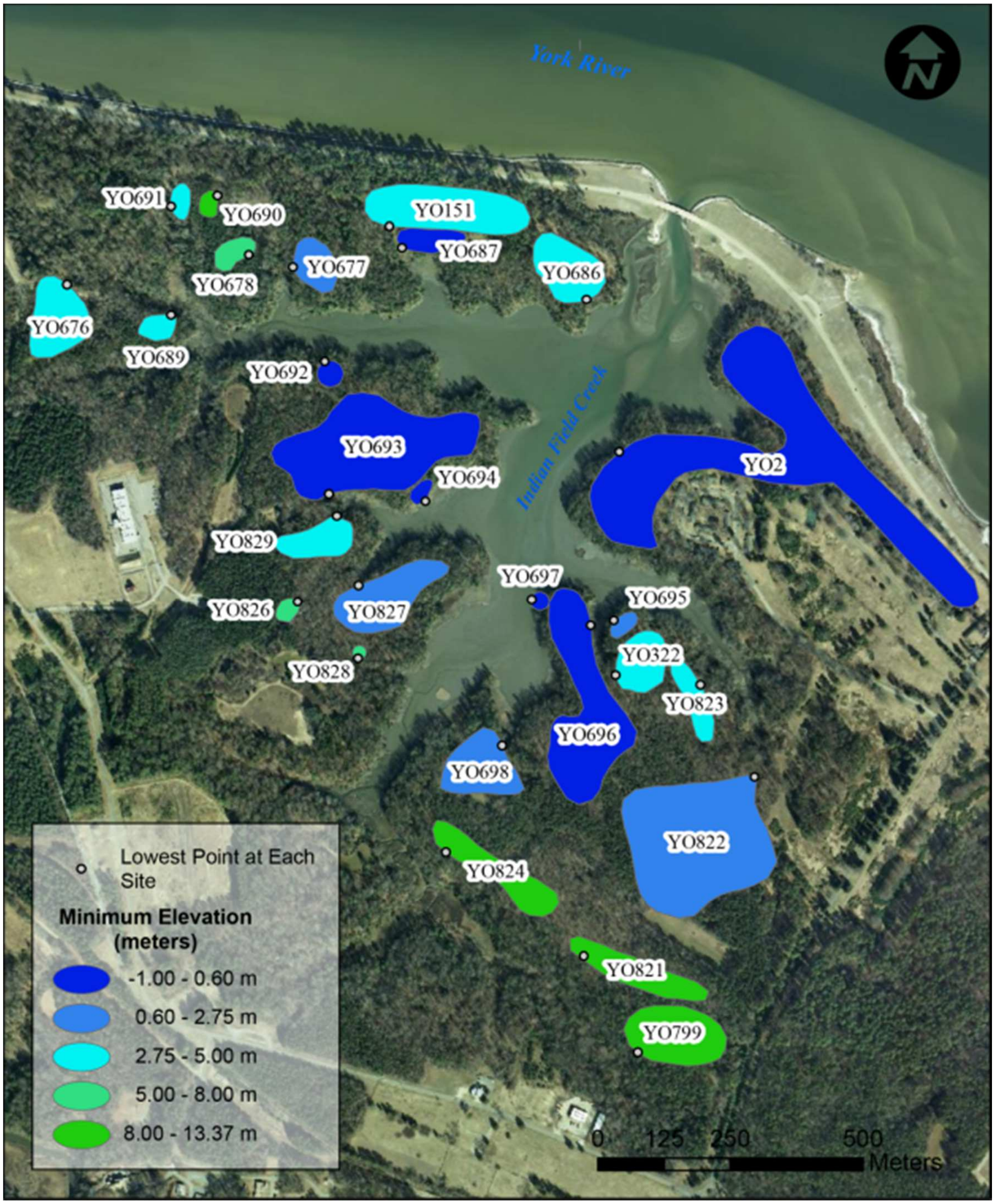

Figure VIII-11. Vulnerability rankings based on minimum elevation. The lowest elevation at each site is also shown.

Site Number	Minimum Elevation (meters)	Rank
YO151	3.28	3
YO2	0.00	5
YO322	4.15	3
YO676	4.17	3
YO677	2.61	4
YO678	6.97	2
YO686	4.32	3
YO687	0.35	5
YO689	3.27	3
YO690	8.35	1
YO691	3.53	3
YO692	0.29	5
YO693	0.51	5
YO694	0.01	5
YO695	2.51	4
YO696	-0.23	5
YO697	-0.95	5
YO698	1.54	4
YO799	11.52	1
YO821	13.37	1
YO822	1.56	4
YO823	4.58	3
YO824	11.47	1
YO826	7.16	2
YO827	1.95	4
YO828	5.10	2
YO829	4.78	3

Table 3. Minimum elevations and vulnerability rankings for the selected sites.

D. Distance to Nearest Drainage

The distance from an archaeological site to the shoreline was a critical factor for Reeder et al. (2010) because regardless of elevation above sea level, sites that are directly adjacent to the shore will be more vulnerable than those that are further inland. In the case of Indian Field Creek, several sites are further away from the creek itself, but they are directly adjacent to tidal wetlands. While these wetlands serve to disperse wave action, they are flooded intermittently following the tide cycles, and so sites located nearby will be more at risk than those that are truly located inland. Because of this, I evaluated the selected sites on their distance to the nearest wetland, and if no wetlands were present they were evaluated on the distance to the nearest shoreline.

I digitized the wetlands surrounding Indian Field Creek from the 2016 land cover dataset from the Virginia Geographic Information Network (VGIN). The boundary of Indian Field Creek was also digitized to provide a boundary where there were no wetlands. Then I used the Near function in ArcMap to determine the nearest point along the wetland boundary to each archaeological site. Figure VIII-12 illustrates these points. The distance between the site and the wetland or shoreline boundary was also calculated, as shown in Table 4. These distances were classified into five categories and given a vulnerability ranking. Closer proximity to the wetland or shoreline yielded a higher vulnerability ranking. These rankings are also shown for each site in Figure VIII-12.

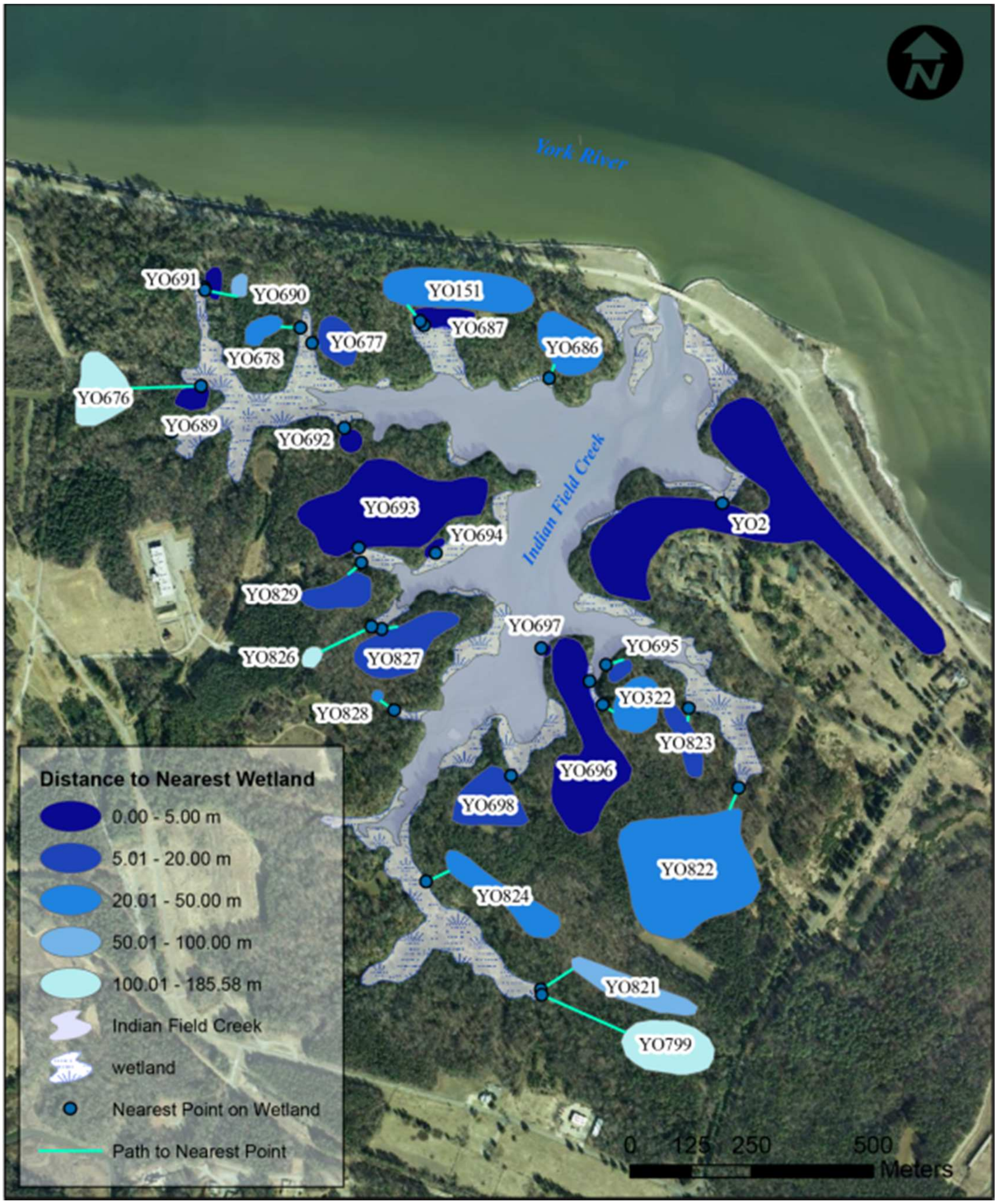

Figure VIII-12. Selected sites ranked based on distance to the nearest wetland or shoreline boundary. The nearest points are indicated with blue dots and the green lines indicate the linear distance between the site and the drainage.

Site Number	Distance to Nearest Wetland (m)
YO151	31.43
YO2	0.00
YO322	21.08
YO676	104.67
YO677	9.16
YO678	37.45
YO686	21.41
YO687	0.00
YO689	0.83
YO690	52.95
YO691	0.09
YO692	4.96
YO693	0.00
YO694	0.00
YO695	10.47
YO696	0.00
YO697	0.00
YO698	8.66
YO799	185.57
YO821	75.38
YO822	41.35
YO823	14.48
YO824	48.80
YO826	113.52
YO827	5.91
YO828	32.55
YO829	19.67

Table 4. Distances from each site to the nearest drainage (wetland or bare shoreline).

Most sites had wetlands adjacent to the majority of their shoreline reach. Only YO695 and YO697 were the only two sites whose nearest point fell on bare shoreline rather than marsh. However, a large distance of shoreline near site YO2 has a very thin margin of wetland or no wetland. It is also interesting to note that a number of the areas that have seen large amounts of historic erosion leading to the creation of new drainages have filled in with wetlands, which is an encouraging sign for the future stability of those areas.

IX. Analysis and Results of Cultural Variables

A. NRHP Eligibility

One of the goals of the Phase II excavations conducted by WMCAR in 2003 was to determine the eligibility of the twelve sites they selected for the National Register of Historic Places (NRHP). Out of those twelve sites, the ones analyzed in this project are 44YO2, 44YO686, 44YO687, 44YO693, and 44YO799. All of these sites were potentially eligible under Criterion D as well as Criterion A because they are associated with the Kiskiak complex. At the end of the Phase II excavation, WMCAR concluded that 44YO686 was not eligible for the NRHP because the integrity of the site was compromised, but the other four sites analyzed here (44YO2, 44YO687, 44YO693, and 44YO799) are all eligible for the NRHP under both Criteria A and D (Blanton et al. 2005).

Beyond these five sites, the remaining 22 sites were classified based on the previous WMCAR survey and the attributes in the site polygon data from

WMCAR (Underwood et al. 2003).[4] All 27 sites fell into one of four categories: eligible, potentially eligible, not eligible, or undetermined. Each of these categories was given a vulnerability ranking between 1 and 5. Since NRHP eligibility was used as a proxy of site significance, the sites that are eligible for the NRHP would be assumed to be the most significant sites in the study area and thus the most important to protect, so they were assigned the highest ranking of 5. Both potentially eligible and undetermined sites could become either eligible or ineligible pending further investigation, so they were assigned values in the middle of the range. Sites that were classified as potentially eligible were given a ranking of 3 and sites that were classified as undetermined were given a ranking of 2. Sites that were determined to be ineligible were given the lowest ranking of 1 because these are usually sites with low artifact density or compromised stratigraphic integrity so the amount of archaeological knowledge we can gather from them is limited.

The results of this analysis can be seen in Table 5 and in Figure IX-1. Looking at Figure IX-1, some spatial patterns stand out. All of the ineligible sites are located on the western shore of Indian Field Creek, to the north of the northernmost tributary. All of the sites along the southern half of Indian Field Creek, with the exception of 44YO799, are either potentially eligible or undetermined, which leaves potential for further excavations.

[4] Since 44YO694 was classified as part of 44YO693 after the WMCAR survey, it was assigned the same value as 44YO693 and listed as eligible.

Site Number	NRHP Eligibility	Eligibility Rank
YO151	UNDETERMINED	2
YO2	ELIGIBLE	5
YO322	UNDETERMINED	2
YO676	POTENTIAL	3
YO677	NOT ELIGIBLE	1
YO678	NOT ELIGIBLE	1
YO686	NOT ELIGIBLE	1
YO687	ELIGIBLE	5
YO689	NOT ELIGIBLE	1
YO690	NOT ELIGIBLE	1
YO691	POTENTIAL	3
YO692	POTENTIAL	3
YO693	ELIGIBLE	5
YO694	ELIGIBLE	5
YO695	POTENTIAL	3
YO696	POTENTIAL	3
YO697	POTENTIAL	3
YO698	POTENTIAL	3
YO799	ELIGIBLE	5
YO821	UNDETERMINED	2
YO822	UNDETERMINED	2
YO823	UNDETERMINED	2
YO824	UNDETERMINED	2
YO826	UNDETERMINED	2
YO827	UNDETERMINED	2
YO828	UNDETERMINED	2
YO829	UNDETERMINED	2

Table 5. NRHP Eligibility values and CVI ranking for the selected sites.

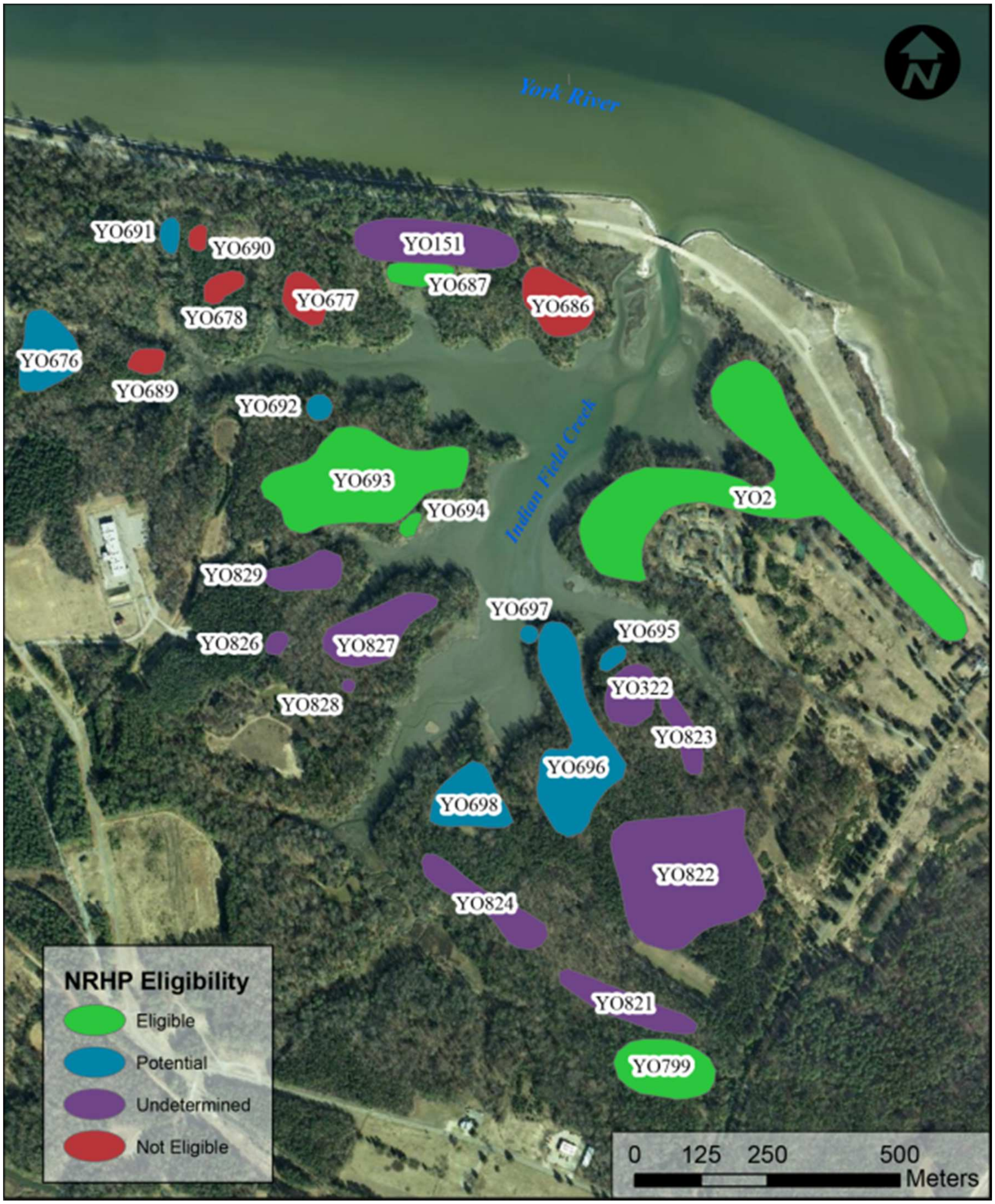

Figure IX-1. NRHP Eligibility for the selected sites.

B. Site Area

The area of each selected site was also used as a proxy for the significance of the site. A large village site would have a more robust archaeological record and would be more important to study than a smaller site with a dispersed scatter of artifacts. Thus, sites with the largest area were ranked the highest (5) while sites with the smallest area were ranked the lowest (1).

Area was calculated using the Calculate Geometry function in the attribute table in ArcMap. Area was calculated in both square meters and in hectares for each site, although the value in square meters was used to calculate the CVI rankings. The results are shown in Figure IX-2 and Table 6.

The areas of the selected sites ranged from 518 square meters (44YO828) to 94,800 square meters (44YO2). Interestingly enough, 44YO2 is about twice as large as the next largest site, which is 44YO822, at 57,400 square meters. These large sites are the exceptions rather than the rule, as the average site area was 15,000 square meters.

Site Number	Area (ha)	Area (sq m)	Ranking
YO2	9.48	94,819.21	5
YO693	4.87	48,670.25	5
YO696	3.54	35,360.45	5
YO822	5.74	57,402.68	5
YO151	2.30	23,034.20	4
YO676	1.32	13,210.36	4
YO686	1.26	12,604.19	4
YO698	1.33	13,340.05	4
YO799	1.72	17,171.48	4
YO821	1.21	12,076.58	4
YO824	1.30	13,029.13	4
YO827	1.65	16,450.95	4
YO322	0.90	8,984.00	3
YO677	0.63	6,341.98	3
YO823	0.60	5,969.80	3
YO829	0.79	7,905.68	3
YO678	0.33	3,264.79	2
YO687	0.48	4,787.32	2
YO689	0.28	2,813.16	2
YO690	0.15	1,458.04	1
YO691	0.21	2,074.23	1
YO692	0.19	1,918.02	1
YO694	0.14	1,350.08	1
YO695	0.16	1,629.25	1
YO697	0.09	942.06	1
YO826	0.15	1,531.03	1
YO828	0.05	518.17	1

Table 6. Sites ranked from largest to smallest CVI ranking based on their area in square meters.

Figure IX-2. CVI rankings for the area of each selected site.

X. Final Coastal Vulnerability Index (CVI) Calculation

After each variable was calculated individually for each selected site, the vulnerability rankings for each variable and each site were compiled. For each site, the average (arithmetic mean) of all of the rankings was calculated to produce a final overall vulnerability score for each site. This allowed the sites to be compared to each other to determine which of them were at the greatest risk. The final CVI matrix is shown in Table 7.

Based on the final CVI results, sites YO693, YO2, and YO687 are the most at risk from future impacts of sea level rise and coastal erosion. YO693 is most vulnerable along the eastern side of the site where the shoreline is eroding at the highest rate. Interestingly enough, the portion of the site originally classified as YO694 is less at risk because the rate of erosion is lower immediately adjacent to that site than further north along that shoreline, as well as having a smaller area than the main YO693 polygon. YO2 is most vulnerable in the cove in the center of the 'Y' where the rate of erosion has been the highest and where the site polygon extends all the way down to the waterline. YO687 is most vulnerable on the southern edge of the site where it abuts the nearshore marsh fringe.

	Historic Rate of Erosion			*Coastal Slope*				*Elevation*		*Distance to Drainage*	
Site Number	EPR (m/yr)	NSM (m)	Erosion Rank	Minimum Slope	Maximum Slope	Average Slope	Slope Rank	Minimum Elevation	Elevation Rank	Distance (m)	Distance Rank
YO693	-0.75	-54.12	5	0.04	78.53	15.03	3	0.51	5	0.00	5
YO2	-0.27	-19.72	3	0.00	136.79	17.92	4.5	0.00	5	0.00	5
YO687	-0.66	-47.51	5	0.04	105.66	15.79	4	0.35	5	0.00	5
YO696	-0.29	-20.63	3	0.03	144.26	14.88	3	-0.23	5	0.00	5
YO692	-0.64	-45.89	5	0.01	105.26	15.05	4	0.29	5	4.96	5
YO694	-0.55	-39.20	4	1.54	78.53	18.96	3	0.01	5	0.00	5
YO151	-0.66	-47.51	5	0.04	105.66	15.79	4	3.28	3	31.43	3
YO698	-0.38	-27.40	4	0.07	62.09	15.37	2	1.54	4	8.66	4
YO322	-0.56	-40.61	4	0.07	133.89	15.83	5	4.15	3	21.08	3
YO827	-0.31	-22.61	3	0.00	86.07	14.43	3	1.95	4	5.91	4
YO829	-0.75	-53.91	5	0.08	79.54	15.38	3	4.78	3	19.67	4
YO677	-0.44	-31.06	4	0.15	90.06	13.17	3	2.61	4	9.16	4
YO695	-0.61	-44.09	5	0.07	70.81	17.99	2	2.51	4	10.47	4
YO697	-0.11	-7.27	2	0.62	59.32	17.56	2	-0.95	5	0.00	5
YO822	-0.15	-10.55	2	0.13	60.15	12.26	2	1.56	4	41.35	3
YO823	-0.14	-9.95	2	0.16	98.71	14.33	3	4.58	3	14.48	4
YO678	-0.41	-29.49	4	0.07	86.49	13.89	3	6.97	2	37.45	3
YO686	-0.15	-10.64	2	0.53	55.50	15.52	2	4.32	3	21.41	3
YO689	-0.05	-3.31	1	0.16	82.12	18.19	3	3.27	3	0.83	5
YO691	-0.05	-3.31	1	0.45	54.48	14.42	2	3.53	3	0.09	5
YO676	-0.05	-3.31	1	0.67	31.17	12.48	1	4.17	3	104.67	1
YO799	-0.06	-4.55	1	0.09	36.09	15.80	1	11.52	1	185.57	1
YO824	-0.06	-4.55	1	0.11	54.85	22.96	2	11.47	1	48.80	3
YO821	-0.06	-4.55	1	0.02	62.71	21.24	2	13.37	1	75.38	2
YO828	-0.06	-4.05	1	0.01	85.05	14.29	3	5.10	2	32.55	3
YO826	-0.15	-10.72	2	0.94	61.36	15.57	2	7.16	2	113.52	1
YO690	-0.05	-3.31	1	0.71	30.25	13.37	1	8.35	1	52.95	2

	NRHP Eligibility		***Site Area***			***Total***
Site Number	NRHP Eligibility	Eligibility Rank	Area (ha)	Area (sq m)	Area Rank	Total CVI
YO693	ELIGIBLE	5	4.87	48,670.25	5	4.67
YO2	ELIGIBLE	5	9.48	94,819.21	5	4.58
YO687	ELIGIBLE	5	0.48	4,787.32	2	4.33
YO696	POTENTIAL	3	3.54	35,360.45	5	4.00
YO692	POTENTIAL	3	0.19	1,918.02	1	3.83
YO694	ELIGIBLE	5	0.14	1,350.08	1	3.83
YO151	UNDETERMINED	2	2.30	23,034.20	4	3.50
YO698	POTENTIAL	3	1.33	13,340.05	4	3.42
YO322	UNDETERMINED	2	0.90	8,984.00	3	3.33
YO827	UNDETERMINED	2	1.65	16,450.95	4	3.33
YO829	UNDETERMINED	2	0.79	7,905.68	3	3.33
YO677	NOT ELIGIBLE	1	0.63	6,341.98	3	3.17
YO695	POTENTIAL	3	0.16	1,629.25	1	3.17
YO697	POTENTIAL	3	0.09	942.06	1	3.00
YO822	UNDETERMINED	2	5.74	57,402.68	5	3.00
YO823	UNDETERMINED	2	0.60	5,969.80	3	2.83
YO678	NOT ELIGIBLE	1	0.33	3,264.79	2	2.50
YO686	NOT ELIGIBLE	1	1.26	12,604.19	4	2.50
YO689	NOT ELIGIBLE	1	0.28	2,813.16	2	2.50
YO691	POTENTIAL	3	0.21	2,074.23	1	2.50
YO676	POTENTIAL	3	1.32	13,210.36	4	2.17
YO799	ELIGIBLE	5	1.72	17,171.48	4	2.17
YO824	UNDETERMINED	2	1.30	13,029.13	4	2.17
YO821	UNDETERMINED	2	1.21	12,076.58	4	2.00
YO828	UNDETERMINED	2	0.05	518.17	1	2.00
YO826	UNDETERMINED	2	0.15	1,531.03	1	1.67
YO690	NOT ELIGIBLE	1	0.15	1,458.04	1	1.17

Table 7. Individual values and rankings for each variable leading to the final CVI calculation for each selected site.

Fortunately, extensive excavations have already been conducted at YO2 and YO687 and so we have gained the most archaeological knowledge from these sites already. The most recent excavations at YO2 have been focused on the area along Mason Row to determine the extent of the Kiskiak village site there. This area is further inland and thus is not threatened by future shoreline erosion. The part of the site immediately adjacent to Indian Field Creek is what is more severely threatened by future coastal processes. This area is the location of several shell middens and has also had several previous excavations, including the Phase II study conducted by WMCAR in 2003 which revealed a fairly comprehensive prehistoric sequence in one test unit, spanning from the Late Archaic to the Protohistoric period (Blanton et al. 2005). Field observations of this portion of the site conducted in June 2016 and July 2017 indicated downslope erosion with shell deposits being washed down the slope into the creek, as can be seen in Figure X-1. This is occurring despite the presence of trees and ground cover on the top of the bluff. In fact, several of the trees have been uprooted by past erosion, causing them to topple over and loosening the soil, which perpetuates higher rates of erosion.

Possible solutions to these problems would be to shore up the bluff using natural solutions. There is a thin fringe of marsh in the cove there, but more *spartina* could be planted there to reinforce the marsh and make it disperse wave action more effectively. Up on top of the bluff, the dead trees could be cleared out and more shrubs could be planted to reduce the amount of downslope erosion. These strategies could help to minimize the amount of shoreline erosion occurring near this site, which would help protect the midden deposits there.

Figure X-1. Field observation at YO2, July 2017. Shell deposits from the midden were being exposed and washed down the slope of the bluff to the creek. Also visible is a tree that has fallen into the creek bed.

Sites YO687 and YO151 share similar vulnerability rankings because they share the same shoreline reach. However, YO151 is less at risk because it is further inland and at a higher elevation than YO687. Currently, the nearshore wetland in front of YO687 is fairly broad, which will help to minimize the amount of erosion at the site. At present, no action needs to be taken here, but it would be prudent to monitor the site conditions in the future. Future sea level rise could inundate both the marsh and the portion of the site that comes right up to the shoreline. Thinning of the marsh fringe in the future would also make the site more vulnerable to inundation and erosion. While YO151 is less vulnerable than YO687, since so little is known about YO151, it might be useful to conduct further surveys there.

Beyond continuing research at YO2 and YO687, YO693 has the greatest potential for future research. It has not been studied as much at YO2 and YO687, so less is known about it. WMCAR did do a Phase II excavation there in which one test unit revealed an Early Woodland deposit. Further excavation at this site could add to our knowledge of settlement and subsistence practices during the Early Woodland period. Additionally, the shoreline along the southeast side of this site has one of the highest rates of erosion in Indian Field Creek, so it would be important to conduct research there before the site is significantly impacted by future erosion. The shoreline there should also be studied further to determine what management solutions would be most effective, since there is a sizable nearshore wetland along the shoreline, however, erosion is still occurring at a high rate.

After YO693, YO2, and YO687, YO696 is ranked as the fourth most vulnerable site in the study area. This is also a large site that contained deposits from multiple prehistoric occupations spanning from the Late Archaic period through the Late Woodland period, followed by a couple of historic occupations (Underwood et al. 2003). The most threatened part of the site is the eastern side where the new drainage has been forming. Additionally, there are no wetlands surrounding the northern point of the ridge that the site is located on; however, fortunately, the historic rate of erosion in that area has been low. A fringe of shell and historic debris was found along the top of this ridge, indicating cultural deposits that would be threatened if the amount of erosion increased (Underwood et al. 2003). Since, to my knowledge, no Phase II excavations have been conducted at this site, it would be beneficial to either resurvey or conduct a Phase II excavation in order to assess the condition of the site and the potential for further research here.

XI. Conclusions and Directions for Further Research

This study has assessed the vulnerability of archaeological sites close to the shoreline of Indian Field Creek. The results indicate which sites are at greatest risk from future damage due to coastal erosion, as well as which sites have the greatest potential for future research. This will aid coastal and cultural resource managers at the Naval Weapons Station in establishing research and conservation priorities.

Moreover, the Coastal Vulnerability Index framework has broad applications for any coastal region. It can be applied to a small number of sites, as shown here, or to thousands of sites along entire shorelines, as was done in

Thieler and Hammar-Klose's work (1999, 2000). Working with a larger study area provides a macro view of the large-scale environmental trends that are occurring, while working with a smaller number of sites, as was done here, allows for the assessment of sites on a case-by-case basis to determine the best management strategies for each one. In both cases, this type of analysis allows coastal and cultural resource managers to focus their attentions on the areas that are most vulnerable and most significant, allowing them to make efficient use of their time and resources.

One flaw in the CVI framework that is worth mentioning is its dependence on the boundedness of sites. Archaeological sites are made up of loci of artifact deposits with varying amounts of artifact frequencies across each site. Thus, they do not exactly correspond to the neat polygons drawn around them to indicate their locations, which are then used in maps and GIS analysis. For instance, when a point within the site polygon is indicated as the lowest elevation at the site, there may not actually be a cultural deposit directly at that point, or it may be a lower density of artifacts than the rest of the site. This problem was alleviated at least in part by the use of shoreline reaches, which then identified the portion of the shoreline closest to the site that was most vulnerable and provided a usable result, regardless of the actual site boundary.

Beyond this, there are ways that this study could be broadened and improved upon. In the context of the York River estuary, the analysis would actually benefit from a larger study area that would allow for the inclusion of variables such as tidal range and geomorphology because there would be more variability across the study area. If more accurate historic elevation data were available, it would be possible to determine the amount of change in both elevation and slope for the study area. This would make it easier to identify where the greatest amounts of land subsidence and erosion were taking place and the rate at which they were occurring. Analysis of the different types of soils in relation to historic rates of erosion would also be beneficial because then it could be predicted which soil types are most prone to erosion. Unfortunately, that was beyond the scope of this study.

These suggestions would expand upon the work presented here, which provides a practical management framework for the protection of the cultural resources surrounding Indian Field Creek. Through the use of geospatial analysis to develop a Coastal Vulnerability Index, I was able to identify which sites within the study area are most threatened by future coastal erosion. I also provided suggestions for future research and management of these sites. Many of these sites contain deep deposits that provide researchers with comprehensive long-term histories of how people lived and interacted with a changing landscape. These archaeological deposits still have much to reveal about the Powhatan village at Kiskiak, in addition to 10,000 years of Native American settlement in the region before that. There is still much we can learn about how these people dwelled, utilized the natural resources around them, and responded to the ever-changing coastal landscape, but only if we learn the best ways to manage that landscape ourselves.

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